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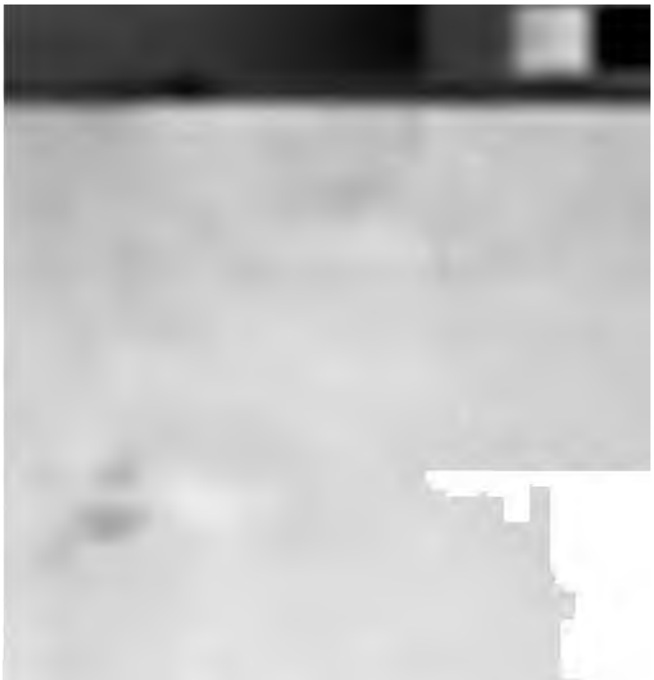

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ELEMENTARY

PHYSICAL GEOGRAPHY

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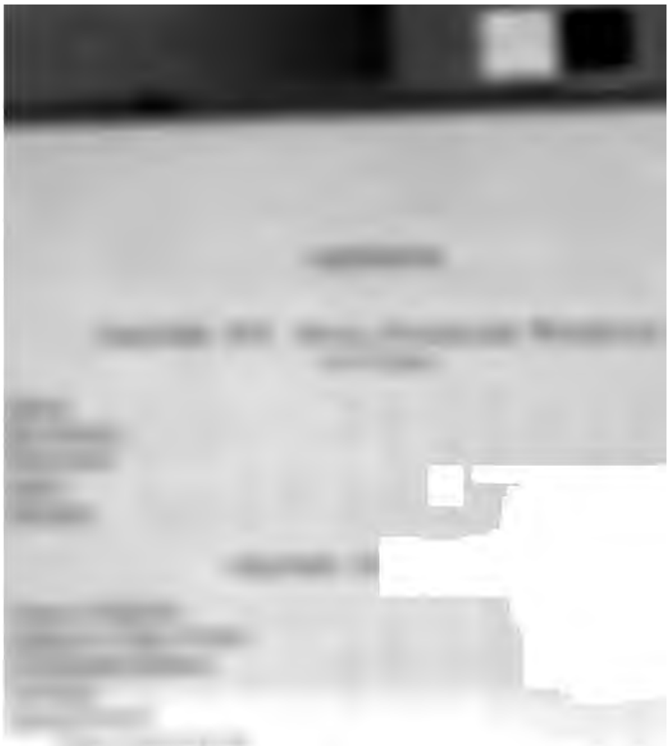

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PLATES AND CHARTS

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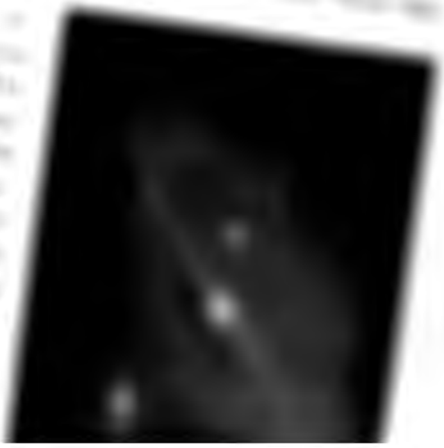

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[illegible] the air is filled with [illegible] of sounds. The lightning [illegible] and [illegible] are produced.

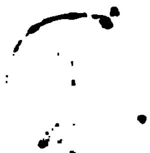
The [illegible] with great intensity [illegible] of the thunder [illegible] of the [illegible] The sound [illegible] lightning [illegible] Heat lightning is often the [illegible] among the clouds, or on the horizon, [illegible] far-distant thunderstorm, perhaps [illegible] of the earth.

[illegible]

[illegible]

[illegible]

our winter when the sun is vertical over that part of the earth which lies between the equator and the tropic of Capricorn, the sun rises in the southern part of the heavens and passes westward without rising high toward the zenith. Then in high latitudes, the sun does not rise above the horizon, and therefore in that region there is no alternation of day and night. In the winter season, in temperate



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long as the vapor condition lasts, but when the vapor is c[illegible] [illegible], the store of heat becomes apparent. Evaporati[illegible] will take place even from a snow surface, but the m[illegible] favorable conditions for the production of water vapor [illegible] warm air in contact with a water surface.

The capacity of the air for water vapor is limited [illegible] when no more can be contained it is said to be saturat[illegible] When there is little vapor in the air it is considerable capa[illegible] of taking more until the point of saturation is reached. [illegible] [illegible] [illegible] If the amount of water upon the land is slight, the air in those pl[illegible] [illegible] [illegible] [illegible] the same with [illegible]

[illegible]

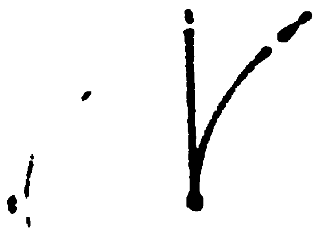
ture of the air and thus increasing the relative humidity [illegible]
[illegible] and changes [illegible] the [illegible] humidity. Fig. [illegible]

It [illegible] from that that there must be very marked diff-
erences in the amount and effect of water vapor contained
the air [illegible] common, the relative humidity is greater
the air [illegible] the point of saturation [illegible]
tropics where the temperature is high, the absolute humid
is high [illegible] vapor [illegible]
[illegible] regions where the temperature
[illegible] the amount of vapor is slight, hence
[illegible]
If the [illegible] the [illegible]

[illegible]

[illegible]

be deflected to one side as a result of the effect of earth's rotation. This tendency tends to turn the course of [illegible] to [illegible] as fast as the course [illegible] In the southern hemisphere the currents are deflected toward the left and in northern hemisphere toward the right and the amount [illegible] speed of the current [illegible] right hand deflection [illegible]



The reason for the defl[illegible]

[illegible]

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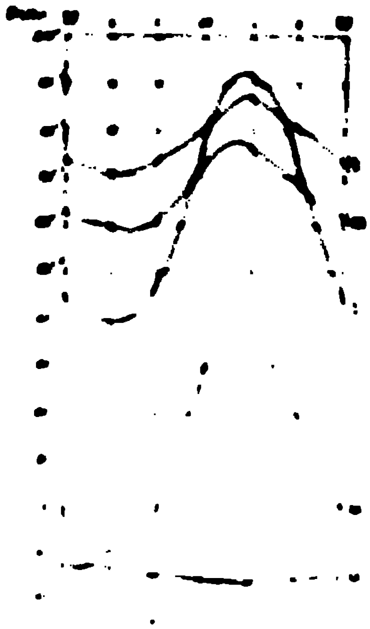
the same, and the divergence from the [illegible] is due to the presence of a number of disturbing influences. These are (1) the effect of atmospheric movements; (2) the influence of the oceans, or the absence of such influence; (3) the effect of topography.



Effect of Atmospheric Movements. [illegible]

temperature range throughout the year is very slight; and in temperate latitudes, while the range is much greater than this, it is still small compared with the range on the land (Fig. 24). Therefore near the seashore, the temperatures of the summer and the day are relatively low, while the temperatures of winter and the night are relatively high. Even on the shores of small lakes this influence of water is noticeable.

On those coasts which are reached by prevailing winds from the ocean, as on the west coast of the United States, the general temperature is high, and the climate equable. Even in a short distance the temperature difference may be very marked; and while on the shore the effect of the ocean is plainly felt, this influence becomes very much less marked at a distance of a few miles from the coast.

Another very important influence of the ocean is that caused by the fact that the water itself is in motion. Both warm and cold ocean currents move on the surface of the sea, and [illegible] the temperature of different parts of the earth. [illegible] warm [illegible] considered [illegible] latitudes where [illegible] differences between [illegible]

[illegible]

[illegible]

[illegible]

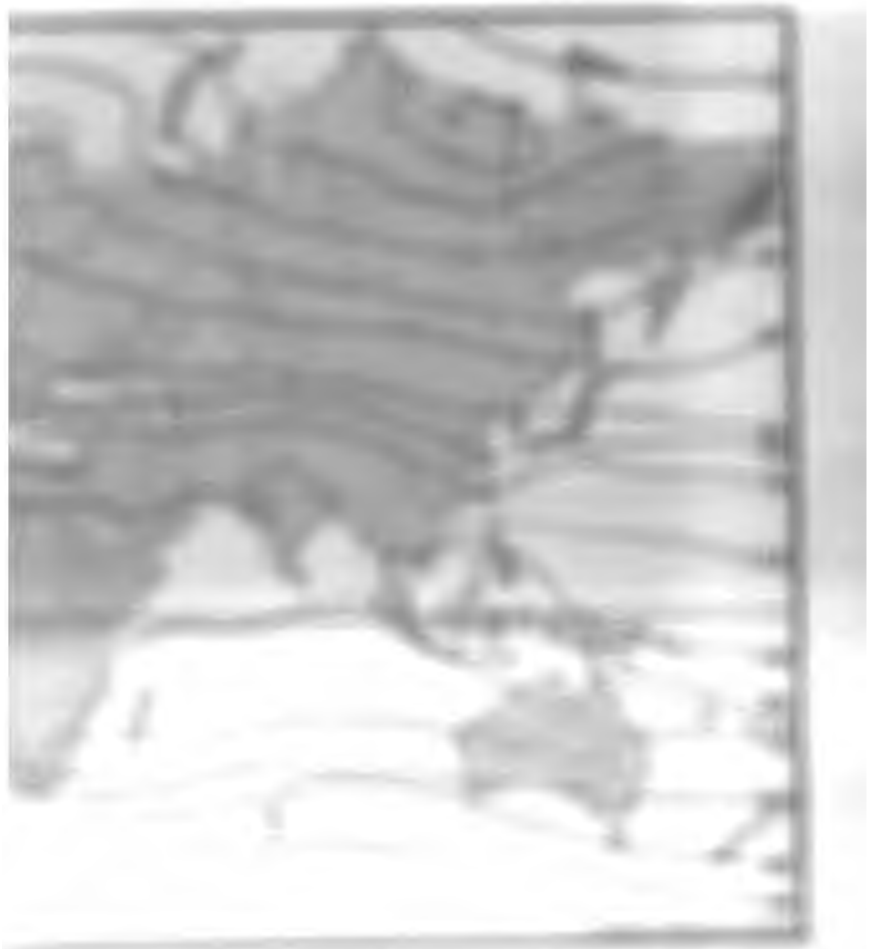
[illegible] upon temperature is shown, sometimes as great differ[illegible] [illegible] wide areas [illegible] and [illegible]. Mountain ranges prevent the passage of [illegible] the great enclosed basins, where de[illegible] and where desert conditions are [illegible] and [illegible] had many [illegible] the influence of land forms upon the distribution of temperatures.

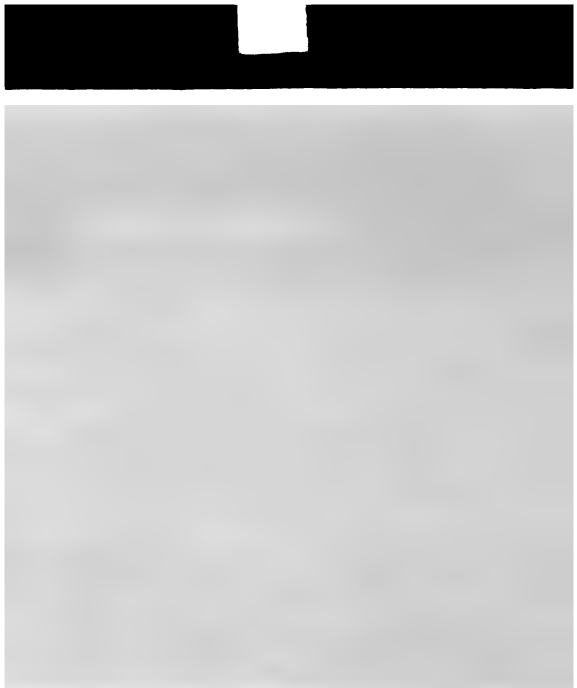
Seasonal Temperature Range. From the above it is seen that [illegible] true indication of temperature [illegible] of many factors which tend to determine climate. It [illegible] one of the most important of the factors, and [illegible] from the equator [illegible]

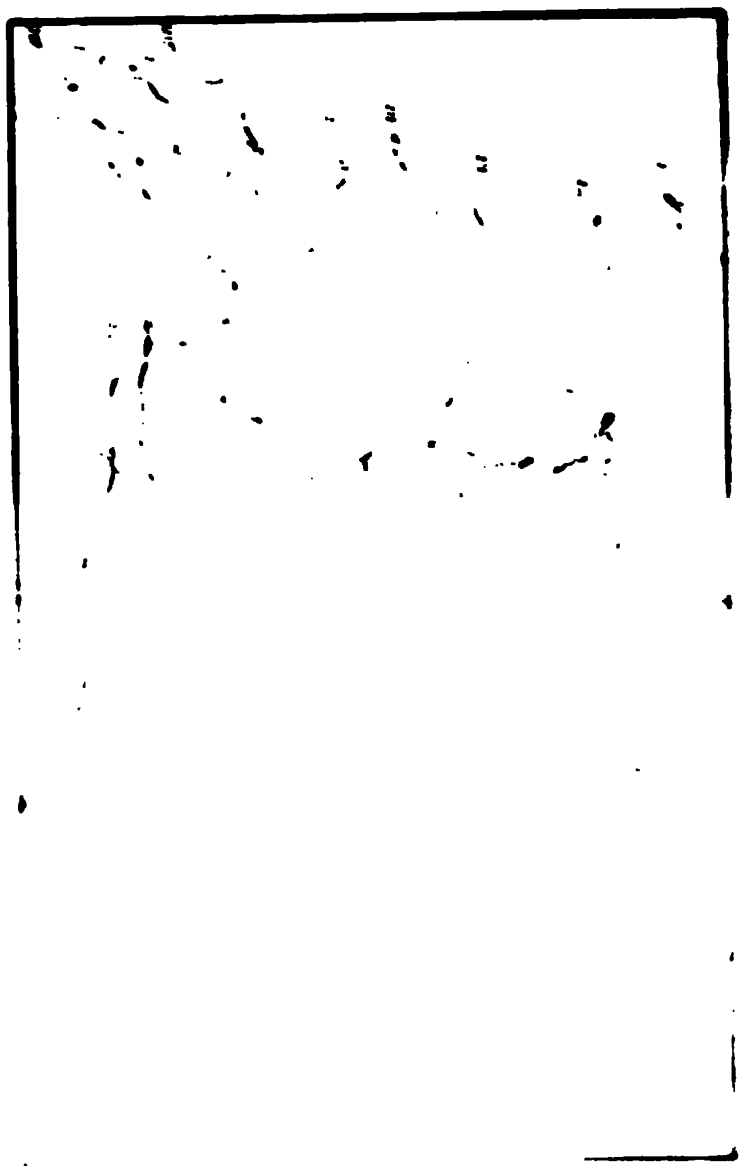
great. On the other hand, in the central parts of continen[illegible] where the winter is relatively cold, and the summer wa[illegible] the curve rises to a much greater height. At the equa[illegible] the curve is much flatter than in temperate and Ar[illegible] latitudes, where the difference between summer and wi[illegible] temperatures is great. In any one of these zones th[illegible] may be marked differences even in neighboring places.

Upon examining one of these seasonal curves, it will [illegible] noticed that the time when the temperature is highest d[illegible] not correspond with the period when the greatest amo[illegible] of heat is received from the sun; nor is the coldest tim[illegible] winter coincident with the shortest day. In other wo[illegible] there is a lagging, and this is due to the cumulative ef[illegible] of the heat or cold. In the early summer, the grou[illegible] is still cool from the effects of the past winter and is [illegible] upon the ground. It takes [illegible]

[illegible]







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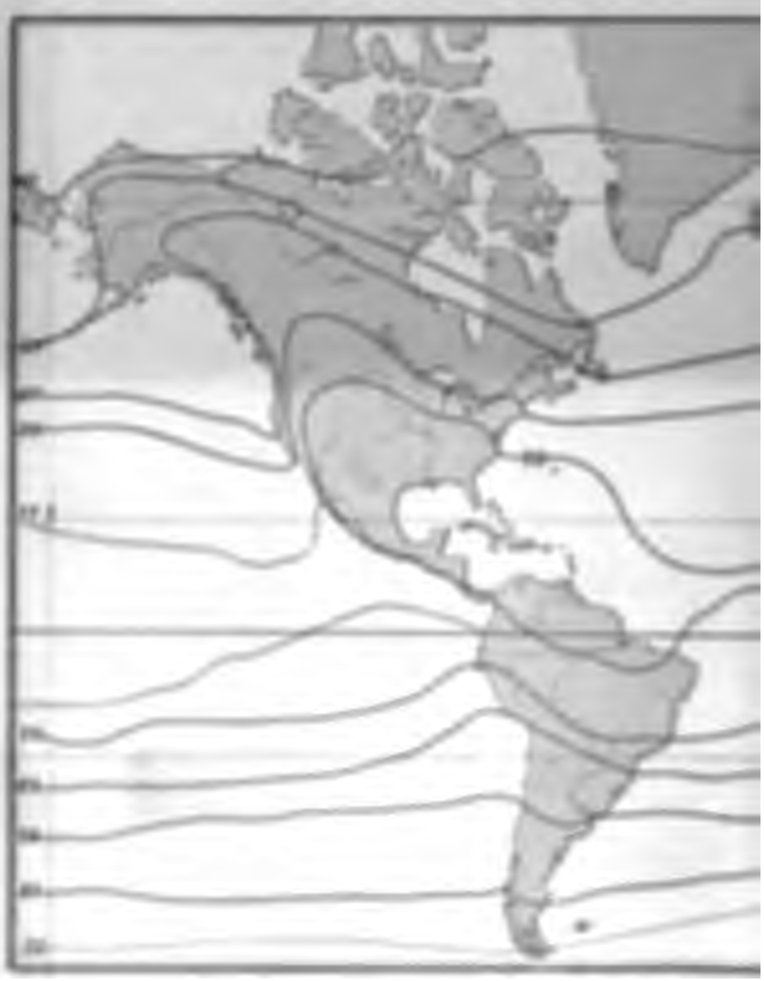

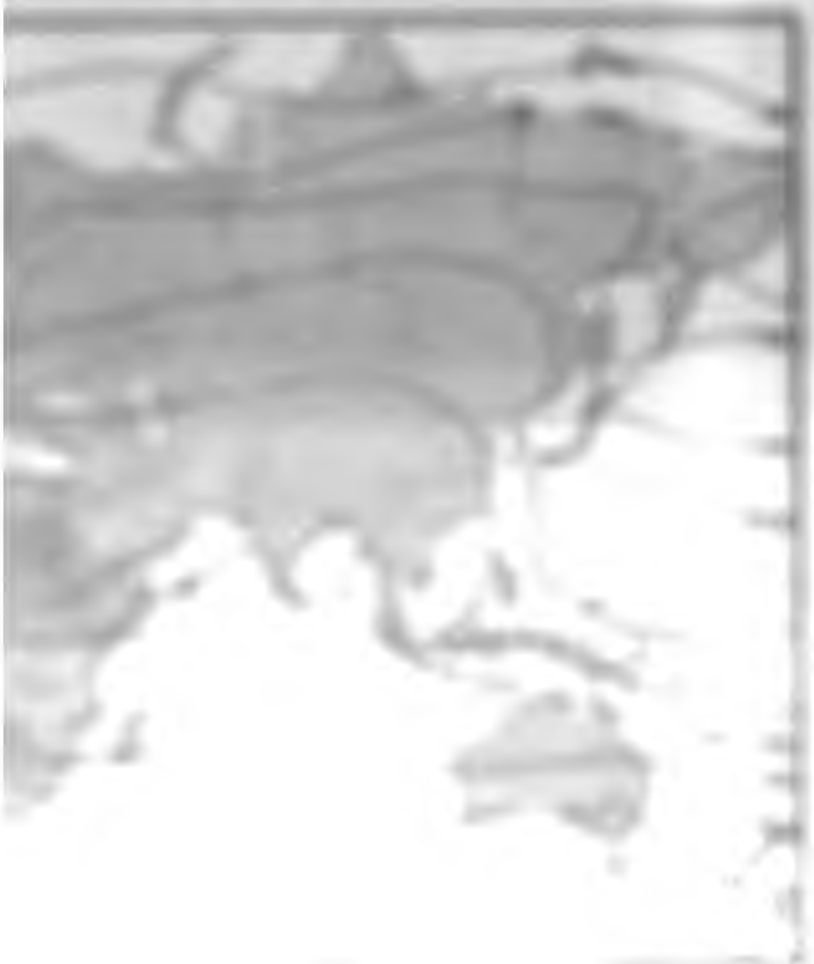

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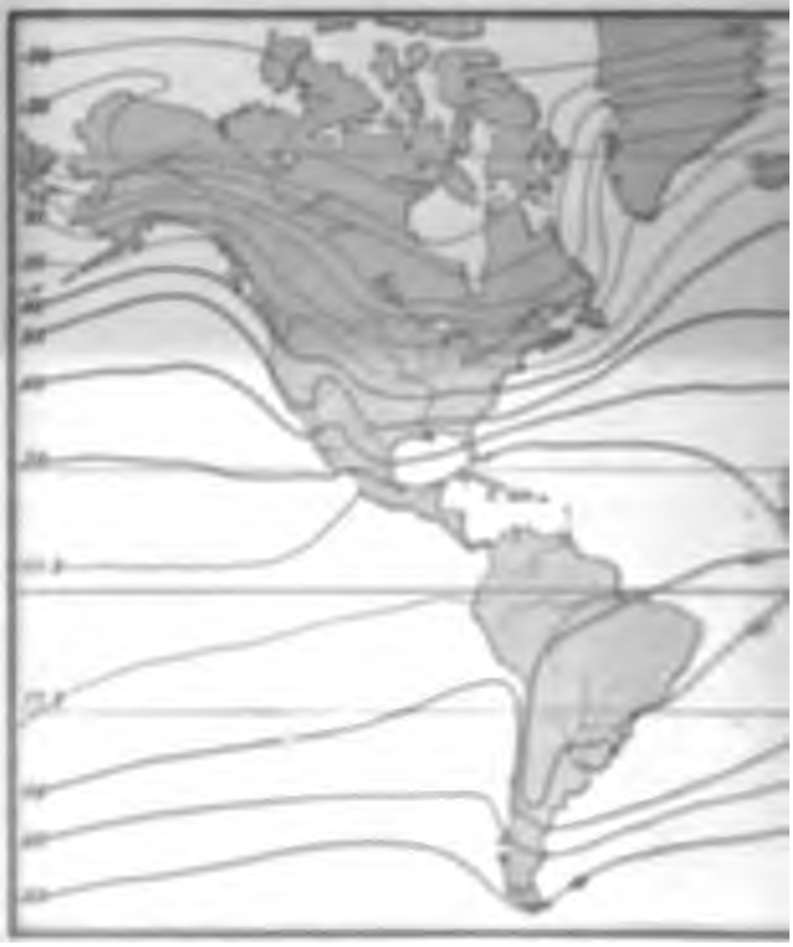
[illegible]

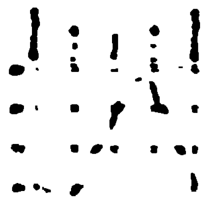
[illegible] than in January it extends beyond the 60th parallel [illegible]. The isotherm of 50° migrates from [illegible] Iceland and Labrador in June to Spain [illegible] in January.

In the higher latitudes of the northern hemisphere the influence of the land is shown by the fact that in January [illegible] temperature [illegible] the interior of [illegible]. [illegible] as far as we know the coldest parts of the earth [illegible] such as Lena. [illegible] found high up [illegible] the [illegible] Siberia near the Arctic circle. This is due to the fact that in these [illegible]

[illegible]



Daily Temperature Curve. [illegible]



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Temperature Ranges [illegible]

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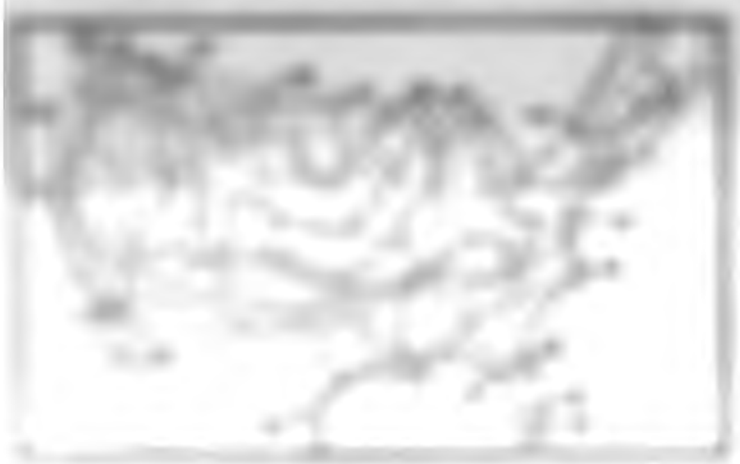
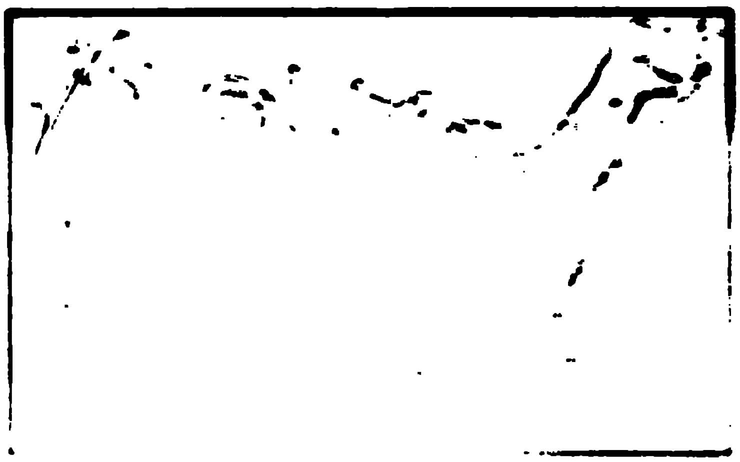


[illegible] at Key West and on the coast of California. In [illegible] the greatest differ- ence [illegible] during the [illegible] is often not over 20 or 30°. [illegible] temperature changes [illegible] 100° (Figs. 30–32).

[illegible] temperature changes [illegible] [illegible] but [illegible] great [illegible] changes [illegible] great changes



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the [illegible] of the [illegible] has [illegible] [illegible], and [illegible] [illegible] [illegible] is [illegible]. In temperate latitudes the difference between summer and winter temperatures is so great that the surface becomes warm in summer and in winter [illegible] to temperatures lower than the freezing point. In the winter in such regions frost [illegible] the ground often to a depth of as great as one or eight feet. In the Arctic regions, where the summers are of brief [illegible] and where radiation is [illegible] the ground is often [illegible] to a depth of several hundred feet. During the summer the surface [illegible] thaws and the [illegible]

and [illegible] [illegible]

earth which is [illegible]

CHAPTER IV.

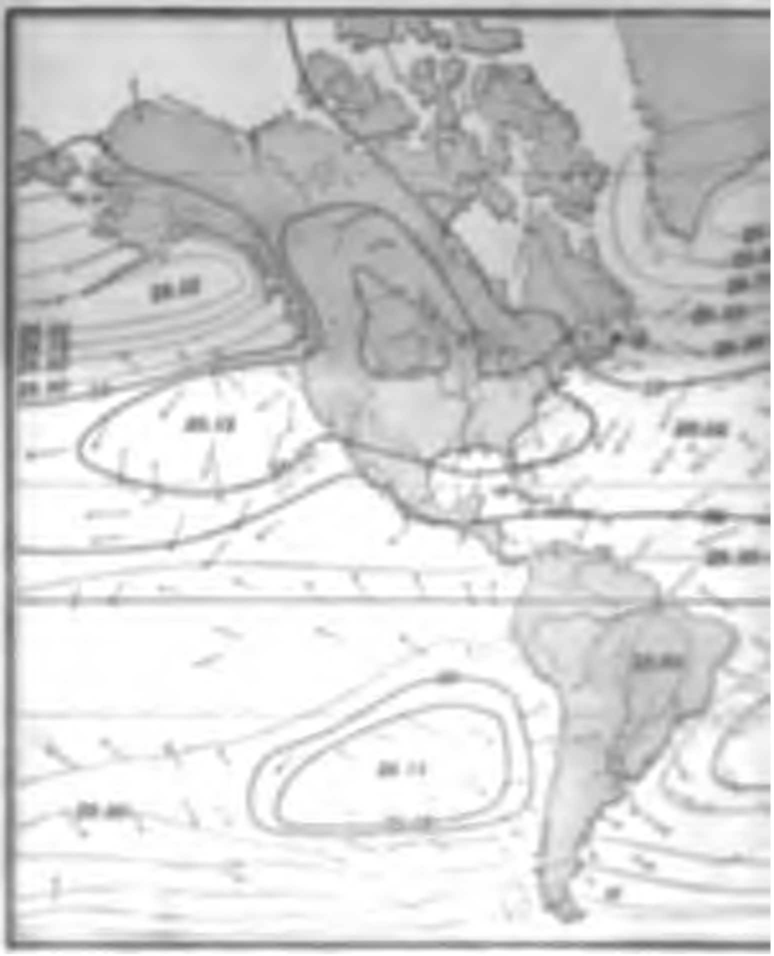
GENERAL CIRCULATION OF THE ATMOSPHERE.

General Statement. — Since the air is very elastic, and condition easily changed by variations in temperature, readily caused to move. No better illustration can be fo of the mobility of the air under these circumstances, that which is so often noticed on heated deserts. The gro becomes warmed, the air is heated by contact with it,

denser, and hence the barometer registers a higher pres of the air. Therefore the relation between air pressure wind is very intimate; and where, for any reason, low-p sure areas exist, winds are found blowing toward (Plate 9). This is the case in certain areas which permanently warmer than the surrounding regions, and in those disturbances of the air which are classed as stor A barometric gradient is produced, and the winds mov if they were going down grade. The air moves away f high and toward low pressure areas.

Classification of the Winds.—For the sake of simplifyin the consideration of the movements of the atmosphere [illegible]

[illegible]



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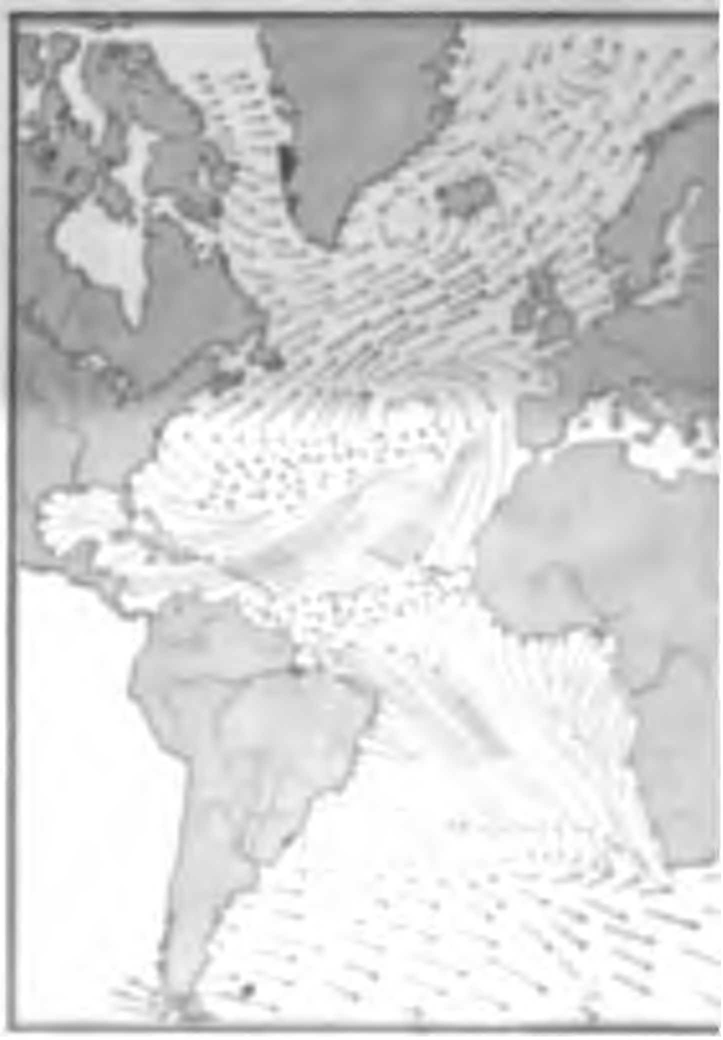


warmer regions, and therefore its capacity for water vapor [illegible] constantly increasing. Therefore they are drying winds, [illegible] when they blow over the ocean, evaporation is rapid, while [illegible] the land, where water vapor is not readily obtained, they p[illegible] deserts in many places. Since the temperature of the air is high, when blowing over the ocean the amount of water vapor which it is enabled to carry is very great; and much rainfall is caused if the air is made to rise, as is the case when the trades blow upon rising coasts.

Doldrum Belt.—Over the heat equator, the air in this great planetary circulation rises by convection; and in this place condition of almost permanent calm is produced (Plates [illegible] and 11). This [illegible] the [illegible] the [illegible]. The doldrum [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] at Cape of Good Hope, and return by way [illegible] p[illegible] m. In the northern hemisphere, the most striki[illegible] [illegible]nence of the prevailing westerlies upon the surface, wa[illegible] [illegible]rom the fact that they determine the path of movement [illegible] he greater number of our storms.

Periodical Winds. — There are certain changes of a peri[illegible] [illegible]al nature, which tend to start the air in motion in a defi[illegible] way; and this tendency is repeated as these periods retu[illegible] [illegible] most important [illegible] changes are those which a[illegible] [illegible]m the variation in [illegible] solar energy in the diffe[illegible] [illegible]easons, and in the cha[illegible] from day to night. The peri[illegible] [illegible]al winds may therefore [illegible] as seasonal and diur[illegible] winds; and in the group may also be included two mi[illegible]

[illegible]

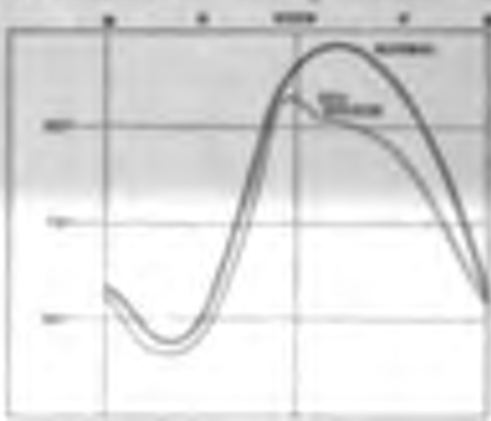
tendency toward inflowing summer and outflowing wi
winds is quite pronounced.

Even where the distinct monsoon condition is not
duced, a tendency to the production of this class of w
often expresses itself in the disturbance of the wind di
tion. This is very well illustrated along the Texas co
where the summer trade winds are deflected until t
blow upon the land. This phenomenon is shown on Pl
10 and 11; and on th
charts it will also be noti
that in the winter, the p
vailing winds of the c
of northern United Sta
are from the land tow
the ocean, while in sum
their direction is m
less definite. That is
say, the prevailing west
ly winds are strengthen
in winter and weaken
in summer by the monso
tendency, which is

that the
... shores.

change in temperature there is produced a local circula[illegible] resembling in a small way the more extensive continen[illegible] or monsoon circulation which depends upon seasonal chan[illegible] in temperature.

Where prevailing winds blow upon the coast, as is o[illegible] the case in the trade wind belt, the intensity of these wi[illegible] is sometimes considerably increased during the day, by [illegible]



combination of [illegible] sea breeze and [illegible] normal wi[illegible] Even on the la[illegible] where no tende[illegible] to the product[illegible] of the sea bre[illegible] is present, [illegible] change in te[illegible] perature betwe[illegible] day and night p[illegible] duces an ef[illegible] [illegible]

[illegible]

[illegible]

Cayuga. At nighttime the air flows down these valleys, producing perceptible breezes. Concentrated in the larger valley occupied by the lake, the wind often develops into a strong breeze during the calm summer nights; and the wind lasts until eight or nine o'clock in the morning. No breeze of the valley type has been noticed here. It is probable that in the other similar valleys of this region the same breeze is produced; and it may be expected in almost any place where the land is deeply cut by valleys.

Eclipse and Tidal Breezes. — These are practically unimportant. During total eclipses of the sun, breezes have been noticed whose origin seems to be due to this occasional interference with the sun's rays. Where tides rise to a great [illegible]

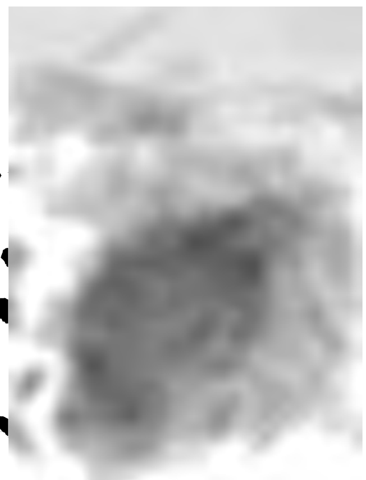
[illegible]

[illegible]

[illegible]

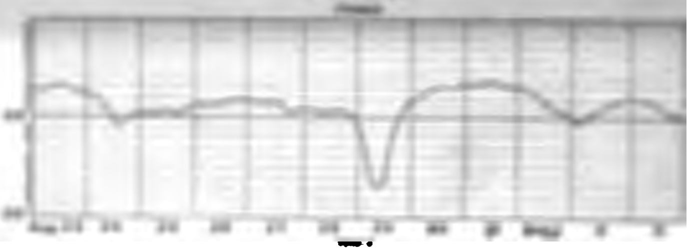
[illegible]

aking movements with their wings. These may be
internal work of the wind which these birds have found, a
made use of in their flight, sorting out those movemen
which they need, and not being retarded by those which
sed to their mo[illegible] been suggested by Profes
angley that it is [illegible] that these air movemen
y be employed [illegible] ation by man himself.

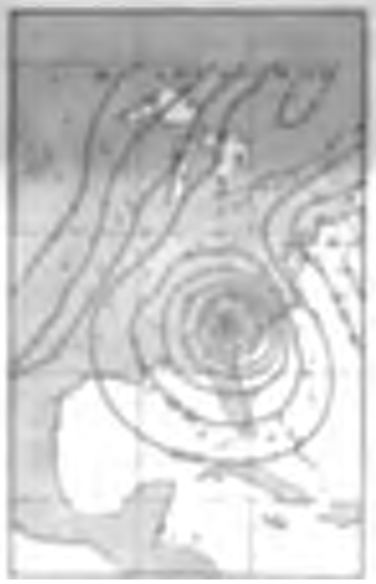


from the rising of the air, and the consequent cooling u the dew-point is reached. In the same way, air that rise a result of convection may reach the dew-point, thus fo ing clouds and rain. These kinds of rainstorms are no particular importance in northern United States, and the fore need not be considered in detail.

These causes *aid* in the formation of the very impor group of storms which bring the greater part of the that falls in the northern half of this country. To these name cyclonic storms may be given; and these are not



whirling air, toward the center of which the winds are blowing from all directions, along spiral courses, as is shown in the accompanying diagrams (Figs. 42, 43, and 44). The hurricane is therefore not unlike the desert dust whirl which was described in the last chapter. Air is moving toward a central area, where it ascends and flows away in the air above. This outflowing of the air in the upper parts of the storm, is shown to some by the movements of the upper clouds, which extend outward as long streamers.



Effects.—The violence of the winds in a hurricane are almost incredible, and many a ship that has been drawn into the dangerous whirl has not been able to escape destruction. The tendency is for a vessel to be whirled around the storm center; and if it happens to pass through the center or "eye of the storm," the sudden change

31, 1876, 100,000 people were killed. Even along the Atlantic coast of the United States, where the hurricanes are of much less violence than in the tropics, a vast amount of destruction is done by them. Not only are ships destroyed, but the low coasts are swept by storm waves (Fig. 82), as has frequently been the case on the New Jersey coast and on the Sea Islands of the Carolina coast.

Path. — In the North Atlantic, the hurricanes usually move first toward the northwest, then they curve and pass along the Atlantic coast of the United States until the latitude of Cape Hatteras is reached, when they generally turn to the right and pass in a northeasterly direction out into the Atlantic, which they often cross (Fig. 42). However, at times they diverge from this path and enter the United States, passing northward into Canada. Then [illegible]

[illegible]

ing surface winds are blowing toward the place of ascent. As a result of the *directly* inflowing air, a whirling ... be produced; and some cause must be found which ... originate the spiral motion of the air. A possible ... for this is the deflective influence of the earth's rotation; but ordinarily this can produce little effect near ... equator, because the difference in the velocity of rotation ... ent latitudes in this belt is very slight (Fig. ... on examining the temperature charts of the world we find that the heat equator is farthest from the ... graphic equator in the late summer and early autumn, ... that it migrates farthest from the equator in the north... hemisphere, while in the Atlantic it is never far south of

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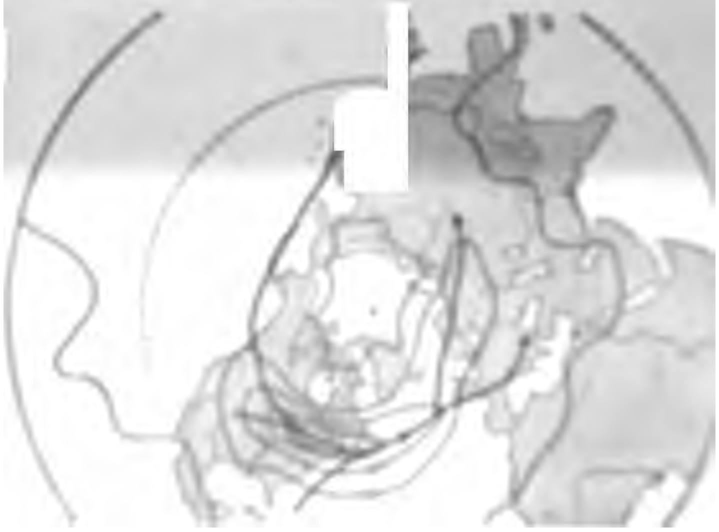
the weather changes of the northern temperate latitudes. The "northeast storms" of New England, so called because they bear damp northeast winds, belong to this class. Every part of the east experiences them, and their importance is very great.

So close is the resemblance between hurricanes and temperate latitude cyclones, that when the latter are violent, it

they are formed, while the temperate latitude cyclones of develop violence as they proceed on their course. While clones may at times become very violent, they never attain intensity which is noticed in some hurricanes. The whirl of the air in the temperate latitude cyclones is not so d tinct as in the hurricanes (Figs. 44 and 46), and, in the there is rarely if ever a distinct "eye."



and pass across the United States, the Atlantic, and Eur
thus going nearly around the earth (Fig. 48). While
path of progression is usually regular, there are many no
irregularities of a peculiar and rather exceptional nat
(Fig. 49). The origin of these is not well understood.

Effects. — The effects of these storms in northern Uni
States are very important; and they are not confined to
region, but occur in Asia, Europe, and the south tempe
latitudes. In the United States, the storms usually co
from the west, and hence from the interior, while in Eur
they come from the ocean. They bring to us the grea
part of our rain and snow; they are the main cause
thunderstorms and tornadoes; they produce many of

[illegible]

[illegible]

[illegible]

... unseasonable rise in the temperature, and snow ... ars before it with great rapidity.

... the western or rear side of cyclones, instead of warm, there are cold winds. Here the air comes from cold northern lands, and in a measure also from the upper layers of the ... When very viol... the ... old north or northwest winds ... known as blizz... y often bear with them vio... ... squalls of snow... home of the blizzard is the ... west; but even ... region of central ... true blizz... that milder form, often ... the severe winte... In Europe, the same ... of wind is develop... in Texas the norther is a wind of similar origin.

[illegible]

[illegible]

[illegible]

convection, if the ascent carries the air high enough for the dew-point to be reached, clouds may form and rain fall. In such cases electricity may be generated, and lightning and thunder may accompany the rain. In the belt of doldrums, the ascent of the moist air causes frequent thunderstorms during the day; and in summer, the rising air among the mountains may cause the formation of thunderclouds and rains. In this class of storm there is no distinct whirl, but a simple ascent of moist air.

In central and eastern United States, thunderstorms are common in summer; and they also are the result of uprising moist air. That this is so, is shown by the fact that they occur almost exclusively in summer, and near the close of hot, sul-

are generally not violent; but there is a steady and often heavy downfall of rain, with accompanying thunder and lightning. In some cases the downpour of rain is excessive; and among the mountains of the west, there are often such torrents of water that the name *cloudburst* is given to them. The name is certainly warranted, for the water falls in sheets, in a manner which can be appreciated only after having seen one. These excessive rains may be due to a supersaturation of the air.

Tornadoes and Waterspouts. — These extraordinarily violent storms are fortunately small, local, and not common in most of the country. Like the dust whirl of the desert, or like the hurricane, they are whirling bodies of air, in which

storm center, while above it there is a colder layer of easter
moving air. Therefore the conditions of the atmosph
are peculiarly unstable; and the increased heat caused by
sun, starts an overturning which soon takes the form o
violent whirl. This is not possible in the far west, wh

the lower air is d
and in the east,
atmosphere is moist
a sufficiently unsta
state for this viol
overturning.

When the storm
develops or passes o
the sea, or even a la

[illegible]

[illegible]

[illegible]

result of the stirring of the air, and the inflow of new supplies of air, wind tends to check dew formation. Because the air is more humid, dew is formed more readily near streams or swamps than in dry places. Dew is heavier in valleys than on hills, partly because of the greater dampness of the valleys, partly because cold air slides down into them from the hillsides, and partly because the air in valleys is more quiet than that on the hilltops.

While the main cause for dew seems to be condensation of vapor from the air, recent studies show that this is not the only cause. At all times plants are furnishing moisture to the air by transpiration. Ordinarily this is evaporated; but at night this evaporation is checked, when the air is

[illegible]

[illegible]

dense, "dust" particles are important in the formation
some fogs. It is believed that the fogginess of London
part depends upon the large amount of dust in the air.

Haze. — At times, and particularly during dry weath
a thin veil of blue haze extends through the atmosphere
partly obscures the distant landscape. Often it is so in
tinct that one notices it only when an unobstructed v

various temperatures often causes cloud formations, and this appears to be the origin of many of the clouds of the upper atmosphere. In reality, fog is a form of cloud, and

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

[illegible]

stead of ice. When best developed, as is the case in summ[illegible] they are the typical thunder heads, which rise from a [illegible] base, at an elevation of about a mile, and extend into the [illegible] often to a height of several thousand feet above [illegible] They consist of a mass of rounded, dome-like clouds, w[illegible] often produce a very fantastic and beautiful effect, pa[illegible]ticularly when lighted by the rays of the setting sun.

These clouds are common, every-day occurrences in [illegible] belt of calms, and in summer they are often produ[illegible] around mountain peaks, and over the heated lowlands. [illegible] these cases their cause is the ascension of warm moist [illegible] and during hot summer days they may often be seen [illegible] form. Over the land, they are much more readily for[illegible]

while in the other case a solid covering of solid snow is l
upon the land, perhaps to stay for months. The clouds
the upper air are mostly made of ice or snow, and mount
peaks that extend into these upper layers, rarely receive
other form of precipitation.

Hail. — At times, particularly in summer, balls of
known as hailstones fall from the clouds, especially in

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] the seasonal change in the wind direction, [illegible] coasts have a dry and a wet season. In the interior [illegible] continents, a condition of relative dryness usually prevails [illegible] is not always a true desert condition, but often one [illegible] semi-aridity, in which the rainfall is not sufficient for [illegible] cessful agriculture. [illegible] may be every gradation be[illegible] tween the humid country and [illegible] desert, passing through the stages of semi-aridity and the climate in which drought [illegible] common.

[illegible] greatest irregul[illegible] of rainfall are noticed [illegible] temperate latitudes; an[illegible] depend in part upon the winds, the topography, [illegible]ighborhood to the sea, and the occurrence of cyclonic storms. In parts of the [illegible]

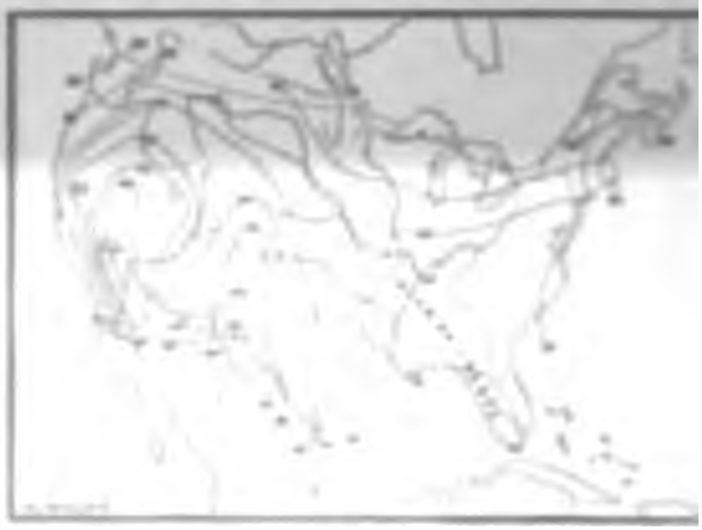
[illegible]

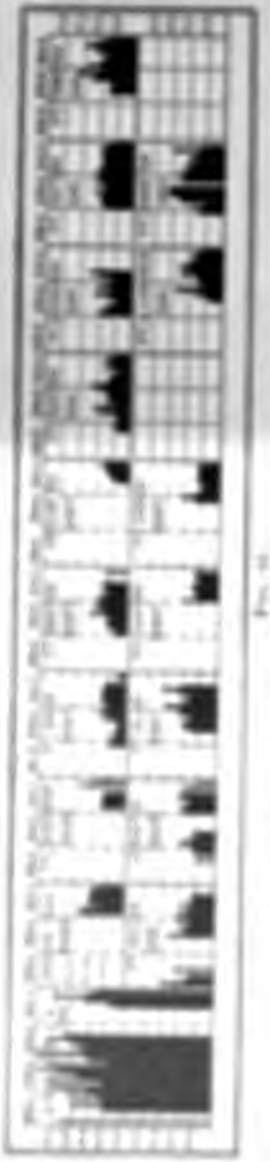
Distribution of Rainfall in the United States. [illegible]

[illegible]

arid. This is due to the fact that in the northern part, winds blow from the ocean against the mountains.

Because of this, the rainfall also decreases very rap from the immediate coast toward the interior. Beyond mountains of the coast, the country is either arid or truly desert condition; and this extends even to the plai states east of the Rocky Mountains. Throughout the gre





produce glaciers as a result o
accumulation of many winters' s
fall. The same is true in pa
the Arctic and Antarctic lands
in these cold places, even the su
precipitation is mostly in the fo
snow.

Seasonal Distribution of Rai
— Many parts of the earth hav
and wet seasons; and as has al
been explained, this is usually
to a change in wind. In equa
Africa, among the headwaters o
Nile, the migration of the be
calms causes such a condition,
the same is true of the llano
Venezuela and the campos of Br
The blowing of the monsoons
the coast of Asia, and elsewh
causes very rainy conditions w
are quite absent when the mon
winds blow from the land. At C
rapunji, where the rainfall is ap
as 500 inches a year, the amount
ing in December is only 0.2 inc
while in July it is over 100 inc
This enormous rainfall, which is
greatest on the earth, is caused
the blowing of the monsoon ag
a steep facing mountain face.
the western coast of the Un
States, particularly in Washing
and Oregon, the winter rainfa

[illegible]

[illegible] [illegible]

[illegible]

R VII.

D CLIMATE

Weather.—Climate is ... and average of wea... which includes the da... ge in temperature, pres... wind, rain, etc. The ... shows the general condi...

[illegible]

[illegible]

[illegible]

[illegible]

and anticyclones, with their accompanying conditions o
rain or clear weather and variable winds. During th
winter, there may be very heavy snowstorms, and at time
extremely violent blizzards; and, following these, the warm
chinook wind may cause an unseasonable rise in temper
ature. Farther south similar conditions prevail, but th
weather changes are less intense. On the dry plains o
Texas, the temperature ranges are extreme; but neither th
chinook nor the blizzard occurs, though a cold norther some
times produces a very severe weather change.

Along the coast of the southern states, high temperature
are experienced, and the ranges from season to season, an
from day to night, are not great. Rainstorms are produce

which radiation proceeds with ease, giving us our cold winter weather; but the cold is not so intense as in the interior area of the northwest.

In the summer, storms are less frequent and less violent, but still they produce an effect upon the weather. When they are not intense, the warm air drawn in from the south produces days of excessive heat and sultriness, during which thunderstorms may come; or a continuation of this condition may cause summer droughts. Along the seacoast, they are sometimes blown in upon the land, or the cool sea breeze may temper the heat of the summer day (Fig. 89). Well-developed cyclonic storms may arise; and in the autumn

ment, and each zone must be subdivided into oceanic, lit-
ly, interior, and upland climates.

Tropical Climate. — Between the tropics, the climate of
the oceans and coasts is mostly warm and equable. The
rainfall is considerable, though to this there are numerous
exceptions, as for instance on those coasts from which the
trade winds blow toward the sea. The doldrum belt is one
of excessive rain and very uniform conditions of tempera-
ture; but that of the trade winds has a more variable
climate. In the interior of the continents, there is more
variation, though the uniform condition is that of high tem-
perature. The temperature ranges are greater than on the
ocean, and the average temperature is also higher.

[illegible]

[illegible]

[illegible]

the great interior region of extreme cold, north of the Great Lakes, emerging across the Labrador peninsula to the Atlantic, in the middle of which the climate is modified by the warm Gulf Stream.

Arctic Climate.—The arctic climate is one of extreme and prolonged cold, and the ground is covered with snow for the greater part of the year. During the winter, the sun remains below the horizon, and in summer it does not set. On high mountains which rise into the cold layers of the upper air,[1] many of the conditions of the arctic climate extend into the temperate, and even into the tropical zones (Fig. 61). Between the tropics, a temperate climate is found at moderate elevations on the mountain sides.

mate varies so remarkably with differences
elevation of land, or in the relation between land and
it is possible that changes of a purely geographic natur
account for some of the variations. If large areas
should be raised to greater elevations, or considerable
be lowered, or if the ocean currents should have their
decidedly changed, the climate of parts of the earth
be very different from the present. Such changes
ave occurred, and in this way some of the climatic vari
may be explained; but at present, only hypothesis
ed to account for the change.

[illegible]

[illegible]

[illegible]

together; but the ocean is so different that it must be considered separately. The mobility of the water, and the moderate temperature ranges over the greater part of the ocean, are both favourable to the widespread distribution of marine life; and thus in great oceans we find some species ranging almost from one end to the other. The limit of temperature is the main check to the spread of ocean animals, and this is well illustrated by the distribution of reef-building corals, which are practically excluded from areas where the water temperature descends below 68°. Because the temperature of the ocean water descends as the depth increases, the forms of life change with the depth.

In the case of ocean plants, as indeed those of fresh-water [illegible]

[illegible]

variety and abundance; for while there are many vicissitudes in the colder zones, everything favors the development of life near the tropics. The animals of the Arctic must prepare themselves for the long, cold winter; and at all times the conditions surrounding them are severe. Only a few forms of mammals exist there, and these are very hardy and well pro-

climatic change from the rigorous winter to the wa
summer.

The influence of temperature upon the abundance a
kind of life, is also illustrated in the ascent of mountain
(Fig. 66). Within the tropics, one may pass upward i
places where plants exist, which in many respects resembl
those of the temperate zone; and in this zone a flora
arctic habit exists upon many of the highest mountain
In studying the distribution of animals and plants, altitu
is found to be a very important factor; and as one ascen

a mountain
he finds
plants and anim
disappearing one
one, and their pl

the seeds. Therefore in the study of geographic distribution of plants, the seeds are of much interest. Some are heavy, and these drop to the ground close by the tree; but in some cases, these heavy seeds are enveloped in a fruit, which is eaten together with the seed; and since the germ is often protected by an indigestible shell, the vital part of these seeds may be carried for long distances, and then be left upon the ground unharmed. Some seeds cling to the

mals of Europe are quite different from those of America; of South America from Africa.[1] Yet there is remarkabl uniformity in the fact that the same large groups are pres ent in each, as if by some means there had been an occa sional connection or communication. Evolution teaches u that animals and plants have been developing from simple

[illegible]

[illegible]

[illegible]

some land bird which is lost on the open sea. In the wa
there are floating logs which may serve as resting plac
and in this way flying animals may be distributed. A fe
years ago, during a violent storm, a sea gull fell exhaust
not far from Ithaca, New York, at a distance of two or th
hundred miles from its ocean home, which was certainly
north of Philadelphia. Naturally, because of this aid of
wind, winged animals are most widely distributed.

Land animals that cannot fly, distribute themselves
moving over the land, each generation pushing its front
line farther than the preceding, provided other conditio
are favorable. As is stated in the next section, there
certain limitations to this natural spread of life.

[illegible]

[illegible]

[illegible]

even in the forests. There are foreign weeds in the fi
foreign birds, insects, and mammals (notably the rat),
pests, or as unnoticed additions to the flora or fauna. T
ancient marsupials are no longer the most important ma
malian possessors of the Australian zone, but man has caus
an invasion of their territory.

Man is killing here and adding there, with the result t
intentionally or unintentionally, he is changing the life zon
but while thus interfering with the natural spread of li
and, in some cases, succeeding in domesticating plants a
animals of one zone to the conditions of another, he is
able to disturb the great *divisions* of tropical, temperat

with this change in amount of salt, there is a variation in the density of the water. Representing fresh water as 1 the *average density* of sea water is 1.028. There are many reasons for variation in the salinity of sea water. Where rivers enter the ocean, the density is decreased by the addition of fresh water; and also where rains are abundant, as they are in the belt of doldrums, the surface water has its density decreased. On the other hand, where evaporation is great, the removal of the fresh water tends to concentrate salts and therefore to increase the density. In the Mediterranean and the Red Sea, the ocean water is relatively dense, and the same is true of the belts of ocean water over which the dry trade winds constantly blow.

Color and Phosphorescence. — The color of the ocean is naturally blue. This is partly due to the fact that the blue tone of the sky is reflected upon the water surface, and partly to the scattering of light rays which enter the water; the cause being analogous to that of the blue color of the sky itself. The color of the bottom often imparts to the water a different shade from the typical blue of the ocean; and where the water is shallow green shades are often produced. The Red Sea owes its color to the presence of many minute forms of vegetation, belonging to the group of Algæ, while the color of the water near some coasts is due to the presence of great quantities of mud brought down by the streams.

At times, particularly on quiet nights, the ocean waters are aglow with a weird gleam of light which is known as phosphorescence. It is similar in origin to the glow of the firefly which we see on warm summer nights. In the surface waters of the ocean there are countless millions of microscopic animals, each of which are able to emit a tiny spark of this strange light, and these present to the ocean is lit up from time to time. Therefore on some

[illegible]

[illegible] [illegible]

[illegible]

[illegible]

topography, and something concerning the kind of bottom as well as the character of the water, and the various physic conditions. For this purpose, one thing is of prime impor tance, namely the depth; and in every deep-sea exploratio this is the first fact obtained.[1] For this sounding, man ingenious contrivances have been invented, the one be

adapted to deep-sea work be ing the Sigsbee deep-sea sound ing machine (Fig. 73). A weight attached to the end of fine steel wire, is carefully low ered until the bottom is reache The ball of the sounding m chine sinks by its own weigh and when it touches botto

sufficient length of time, it is drawn to the surface and its contents examined.

Imagine a balloon sailing through the air at a height of three miles or more, and dragging a frame a few feet in length, over a distance of a few miles. If the operators of this apparatus should imagine that, as a result of a few trips, they had obtained a fair knowledge of the life existing on the surface of the earth, it will readily be seen that they would be very much mistaken. All swiftly moving animals would escape, and only those would be taken which were small enough to enter the dredge, and so slow that they could not escape from it. In a measure this is true of all explorations of the deep sea. If large animals exist the

distance of about 80 miles. Within sight of the Bermu
at a distance of from 15 to 20 miles f
land, the ocean reaches a depth of
2700 to 2900 fathoms. Among the
islands of the Pacific, differences in
tion fully as great as these are freque
discovered. On the land there are
such excessive differences in elevatio
those which exist among the
islands of the ocean.

The Atlantic Ocean. — Perhaps the
way to obtain an idea of the topogra
of the Atlantic Ocean, is to make a
tion across it, following approximat
the line traversed by the
(Fig. 76). Starting from the
New York, an even, gently sloping
is found stretching eastward to a dista
of from 50 to 75 miles. It is
level, and its features are quite like
of the very level plains on the land.
plain extends far above the mouth of
... including nearly all of
... between the present New Engl
... and a line about 100 miles
the ... South of New York this
... continental shelf

[illegible]

[illegible]

[illegible]

oceanic plateau rises toward the continent. Here the con- ditions that were noticed off the American shore are prac- tically repeated. There is a slope and then a continen shelf, which merges into the continent itself. In the vicin of the British Isles the shelf is broader than it is along coasts of France and Spain.

Other Oceans.—Much less is known concerning the con- ditions in the depths of the Pacific; and almost nothing known concerning the Arctic and Antarctic oceans. So as our knowledge of the Pacific and Indian oceans warra any definite conclusions, we may say that the condition the Atlantic are in a general way repeated. The gr monotonous plain is more broken by volcanic peaks; an greater depth is found in the Pacific than in any other of the ocean (see Plate [illegible]). Depths greater than 4000 fa oms have been discovered in several places; and in one pl near the Kurile Islands, a sounding of [illegible] fathoms made. The deepest place in the Atlantic ([illegible] fathoms near Porto Rico. It is a noticeable fact that these unusu depths are found close to the land. While the greatest [illegible] the average oceanic depth is [illegible] of the average land elevation; and the gr [illegible] a considerable distance from the [illegible] the high mountain peak [illegible] above sea level. [illegible] almost directly from the

Topography [illegible] While the description [illegible] present the features of [illegible] concerning the [illegible] continental margins,

exceedingly irregular. Without entering into the subj
in very great detail, these irregularities could not be a
quately described; and indeed, our knowledge of the larg
part of the ocean floor is so slight, that as yet we know o
the general features.

Temperature of the Ocean Bottom. — In the neighborho
of continents, where the depths of the sea are relativ
slight, the temperature is more or less irregular, and det
mined by local conditions. It changes with the seasons, a
is influenced by the oceanic and tidal currents, and even
the prevailing winds.

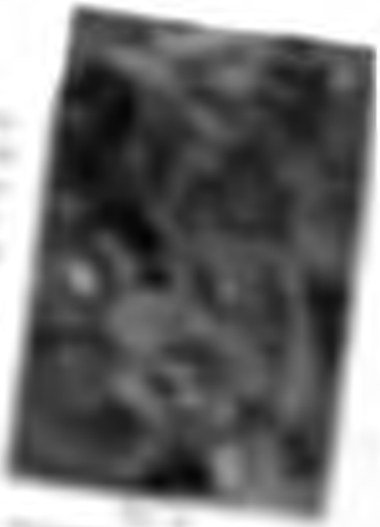
After passing this shallow and variable zone, very unifo
temperature conditions are encountered. As a general st

sence, it still seems certain that some kind of light does ex[illegible] there. This conclusion is forced upon us by the fact th[illegible] many of the animals in the depths of the sea have we[illegible] developed eyes; and, further, that many of them are bri[illegible]liantly colored. Animals living in dark caves become blin[illegible] and it seems hardly probable that these inhabitants of t[illegible] deep sea would continue to develop eyes for ages after th[illegible] usefulness had ceased.

Phosphorescence is a possible source of light on the oce[illegible] floor. After nightfall, whenever a dredge-load of materi[illegible] is brought from the deep sea to the surface, it is aglow wi[illegible] the dull white light of phosphorescence. Each animal, ev[illegible] particle of mud, gleams with this light.

Materials composing the Ocean Floor; Mechanical Se[illegible]diments. — There are two classes of substances spread over t[illegible] ocean bottom: one mainly derived from the land, as th[illegible] fragments of rock washed from sediments; the other, fr[illegible] animals which have lived in the ocean. The latter compose[illegible] [illegible]

[illegible]



It is not exclusively made of the residue of the shel[ls] of surface animals, but contains contributions from oth[er] sources. The most common addition comes from pum[ice] rocks, which were ejected from volcanoes, and after floati[ng] for some time settled to the ocean bottom at some dista[nt] point. Therefore, remnants of volcanic ash or pumice a[re] common in the red zone. Aside from this, there are fra[g]ments of meteorites which have dropped to the bottom, indicating exceedingly slow accumulation. This depo[sit] covers an area of over 51,000,000 square miles, which is [a] little more than that covered by the Globigerina ooze. Ea[ch] kind of deposit covers an area equal to about one-fourth [of] the earth's surface.

Life in the Ocean: *Pelagic or Surface Faunas.*—Th[e] ocean is the great meeting ground of the life of th[e] provinces,—the air, the land, and the water. Forms belon[g]ing to all the great groups of the animal kingdom find [it] possible to live in the conditions which exist in the ocea[n]. There the conditions of life are remarkably uniform; [illegible] there are few changes in temperature, and few variations [illegible] [illegible] This affect day, and [illegible] [illegible] the surrounding conditions are nearly the sam[e]. [illegible] difference is met between the surface faunas of t[he] [illegible] as between the land animals [of] the tropics and the temperate latitudes. This is part[ly] because the temperature of the water changes very slow[ly] [illegible] and it is also in part due to the fact th[at] [illegible] in movement, so that [illegible] distributed to [illegible] bodies of warm wat[er] [illegible] and these may [illegible] the surface of the ocean.

So uniform are the conditions of temperature, that [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

other part of the ocean. There is no such monotony conditions as we find at the surface of the ocean away fr the land. But from day to day, from season to season, a from place to place, there are very marked differences in t conditions upon which the animals depend for their existen and variety. Here, as in every part of the ocean, tempe ture is a very important cause for differences in livi and for variations in animal forms. Even a few degrees temperature will cause a very marked difference in t

abundance a variety of a nal life. Th is well ill trated on t coast of Ma

[illegible]

the presence of a great pressure of water in the depths the sea. The more highly organized animals, such as t true fishes, are unable to accommodate themselves to change in condition; and when they are drawn to surface, they are commonly broken by the expansion the gases within the body. Their eyes protrude from head, the air bladder extends from the mouth, and the is cracked and fissured. Thus while they may live w immense pressures upon every particle of the body, they unable to exist when the pressure is removed from outside, while it still partly remains on the inside.

As a result of deep-sea exploration, it has been found all the ordinary types of marine animals exist on the

[illegible]

[illegible]

[illegible]

this is far from being true; and yet they are constan
supplying to the water a certain amount of carbonic acid
which in the course of time would tend to so vitiate
water that life would not exist.

This is one of the strongest arguments in favor of a
culation of the waters along the bottom of the ocean, f
polar to tropical regions. There must be some supply
oxygen furnished to these deep-sea animals, otherwise t
could not exist; and there is no other supply known
that which may be brought by this great oceanic circulation

Since everything points to the conclusion that this
of ocean movements along the bottom is very slow, it is

[illegible]

CHAPTER X.

OCEAN WAVES AND CURRENTS.

Wind Waves.[1] — As a result of friction between wind and water, the ocean surface is readily started in motion in a

and it dashes upon the coast in the form of a breaker (Fig. 81). The wave is such a shallow movement in the water that it is readily destroyed upon reaching an irregular coast. Thus in harbors or bays, the violent ocean waves lose their force, largely because of friction upon the sides and bottom.

A very slight breeze will cause a series of wave-like movements or ripples; but as the wind continues, and its force increases, the water surface may be thrown into a series of great undulations. The water is so mobile that these wave movements are transmitted for great distances, and they often extend far beyond the place of origin. One may see this illustrated upon the surface of almost any lake

If we watch the rushing of the waves against expo coasts, or the breaking of the rollers upon the slopi beaches, we are able to form some conception of the v amount of destructive work that these oceanic agents m do in the course of long periods of time. With every ru of the water upon the beach, pebbles and sand are dragg backward and forward; and this constant friction of o particle upon another, in the course of time will cause ev the hardest rocks to wear away. In the course of a fe years fragments of brick or glass become rounded, so th they resemble the form of the true beach pebbles; and in year or two a brick may be reduced to a pebble only a sm fraction of the size of the original.

Earthquake Waves. — When an earthquake shock distur the waters of the ocean, a great wave is formed, whi extends from the bottom of the sea to the surface, a which is therefore much more profound in its effect than t shallow wind waves. In the mid-ocean these earthqua waves may not be perceptible; but as they reach shall coasts, they may become noticeable as their elevation increased in the shallowing water. Upon reaching coa not far from the point of origin they may have a height from 50 to 100 feet, which gives them the power of rushi upon the shore for a much greater distance than ordina waves are capable of doing.

Through some earthquake shocks the water wave [illegible] attended [illegible] scenes of [illegible] [illegible] of South America [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

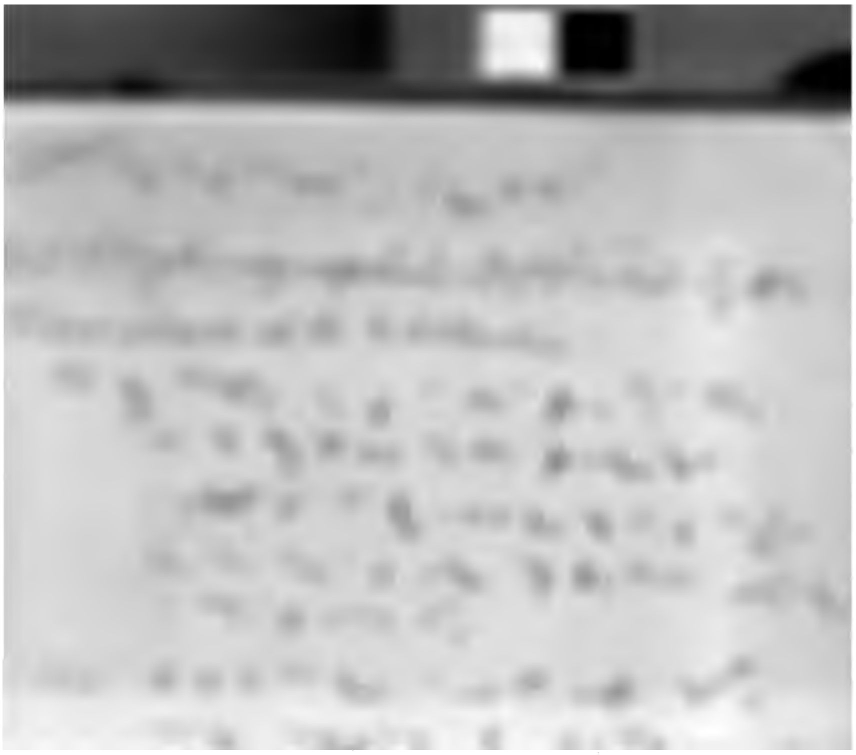
(Plates 15 and 27). As in the case of the atmosphere, th
regularity of distribution is interfered with by numer
causes, mainly the influence of land, and air and wat
movements (Plates 15 and 27). The influence of the ocea
currents is shown in both of these maps, and they also sho

the greater regularity of the ocean surfa
isotherms in the southern hemisphere, whe
there is little land.

Near the coast the temperatures of th
ocean surface are subjected to very marke
variations. This is particularly true in th
temperate zones, where the difference be
tween summer and winter temperatures i
very great. Thus, on the New Englan

little reason for decided changes in temperature, eit
between the day and night, or between the seasons.

Ocean Currents: *Planetary Circulation.*—As a result
differences in temperature between polar and tropical
gions, the air is engaged in a series of great movemen
There are many reasons for believing that a similar cir
lation exists in the ocean. The fact of the difference
temperature suggests the probability of such a circulati
which would consist of a rising of the water under
equator, a surface outflow from equatorial to polar regio
and then a downsinking to the bottom, from which th
would be a return to the equatorial regions along the oc
bottom.



[illegible]

[illegible]

[illegible]

[illegible]

European shore is warmed.[1] A branch extends northw[ard] into the Arctic, while a part returns as a surface curre[nt] along the coast of Spain and Africa, there joining the equa[to]rial drift. The water thus eddies around in the Nor[th] Atlantic, moving northward, then eastward, southward, an[d] southwestward, thus establishing a complete whirl. Anoth[er] important current in the North Atlantic is the cold Labr[a]dor current (see p. 187).

In the South Atlantic a similar whirl of water is const[ant], but this is distinctly less pronounced than that of the Nor[th] Atlantic, and there is no current so marked as the Gu[lf] Stream. Cold water from the Antarctic extends northwa[rd] into the South Atlantic.

In the North Pacific a circulation is established whi[ch] very closely resembles that of the North Atlantic. A bra[nch of the] equatorial drift passes westward toward the Asiatic coa[st] [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

layers of water would cause sufficient expansion to neces
tate their rise to the surface; but this is not the case.

If temperature differences account for ocean currents, th
fact of the greater development of the systems in the north
ern oceans would be difficult to explain. The Antarctic
practically open to both Atlantic and Pacific, and in th
hemisphere there is an excellent opportunity for an exchang
of polar and tropical waters. But the Arctic is almost com
pletely shut off from the Pacific, and is only open to th
Atlantic through narrow and rather shallow channel
Therefore, in the hemisphere where the least favorable con
ditions for an exchange of water exist, we have the be
developed currents. In the North Pacific there seems abs
lutely no chance for the general passage of cold northe
waters along the bottom to the equator.

This and other reasons, such for instance as the presenc
of cold surface currents returning from the Arctic, cas
grave doubt as to the validity of the temperature theor

[illegible]

[illegible]

[illegible]

one of the most rapidly moving of ocean currents, and i
rapidity depends upon the peculiar effect of irregularities

[illegible]

[illegible]

[illegible]

[illegible]

equatorial regions would remain there, while the cold [illegible]
high latitudes would increase, and the temperature [illegible]
these regions would be reduced to very low degrees. T[illegible]
equatorial regions would be much hotter than at prese[illegible]
while the high temperate and arctic belts would be cold[illegible]
The immense influence of these currents is shown by [illegible]
fact that in the latitude of Labrador, — a bleak, inhospita[illegible]
land, — there are powerful and well-populated countries[illegible]
the other side of the ocean. In the one case, cold [illegible]
currents flow along the coast; in the other, the climate [illegible]
tempered by the warm ocean current.

Ocean streams carry vastly more heat than air curre[illegible]
are capable of doing. Croll has estimated that the [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

CHAPTER XI.

TIDES.

Nature of the Tidal Wave. — Each day the ocean sur[illegible] is disturbed by two waves which pass about the earth [illegible] great rapidity (fully 500 miles an hour in the Atlantic), [illegible] affect the entire ocean, from surface to bottom. The a[illegible] height of the tidal wave is very slight, and sailing vessel[illegible] the mid-ocean are never aware of its existence. Wh[illegible] approaches the shore, the wave is subjected to a variet[illegible] complex changes, which make it an important feature of [illegible] … On the coast, the water gradually rises or flows, [illegible] as gradually falls or ebbs; and this is repeated, with [illegible] … twice each day.

Cause of Tides. — … the tide is … with the … of the moon and sun upon the earth. … a mutual attraction which … the effect of this … [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

water in the southern hemisphere, than in the northe[illegible] The continents interfere with the movement of the wa[illegible] and in some cases successfully check it. When the wa[illegible] enters the Atlantic, its direction is changed from west [illegible] north, and soon the wave is so changed that it advan[illegible] more rapidly in the middle part of the ocean than on [illegible] margins (Plate 18). This is due to the effect of the shal[illegible] waters near the continents. The wave is retarded near [illegible] shore and advances more rapidly in the central portion [illegible] the ocean. As a result of this, the crest of a wave may ha[illegible] reached the latitude of Newfoundland at the same time th[illegible] the margins are affecting the coast of northern Africa a[illegible] the West Indies.

In a similar way this effect of friction is also shown in [illegible] bays and larger estuaries. Thus as the wave passes up [illegible] Bay of Fundy, friction with the shore causes it to be [illegible] while in the central part of the bay the wave advances more rapidly.

[illegible]

same wave goes around the eastern end of Long Island
Long Island Sound (Fig. 84). Here its rate of motion

FIG. 84.

Diagram to show path pursued by the tides on the two sides of Hell Gate. Figures represent heights of tides at different points.

retarded, the
Sound
greater, and
Hell Gate
and the two
of the same
arrive at
different
(Fig. 85).
in one of the
seen that the
Hell Gate.

[illegible]

[illegible]

[illegible]

[illegible]

Nantucket, is one of relatively rapid tidal currents. T
rapid currents in the straits between two such bodies
water, may be called *tidal races*.

A tidal race is produced at Hell Gate, near New Yo
City, mainly because the tide rises higher in Long Isla
Sound than it does in the bay of New York Harbor (Figs.
and 85). The very rapid currents in this shallow strait,
in part due to this cause, and in part to the fact that t
time of high tide is different on the two sides of Hell Ga
Similar tidal races occur on many parts of the irregu
northern shore, and at times currents are produced wh
are as violent as rapidly moving streams. In some case

are pulling upon the earth at an angle, and then unusually weak or low tides, known as *neap tides*, are produced.

In the movement of the moon around the earth, it follows a path which is quite elliptical. Therefore, since the earth is at one of the foci, there is a time during every lunar month when the moon is much nearer the earth than when it is in the opposite part of its elliptical path. When the moon is nearest to the earth, it is said to be in *perigee*, and when farthest from the earth, in *apogee*. Since the tide-producing force varies greatly with the distance, this difference in lunar distance produces a very marked effect upon

[illegible]

[illegible]

[illegible]

[illegible]

Where the tide rises in the mouths of rivers or in estuaries, as in Chesapeake and Delaware bays, the rise of the tide checks the river water, and causes it to deposit what sediment it is carrying, so that this effect is also important in modifying the bottom of these bays (Fig. [illegible]). Many harbors are being filled by this means, and millions of dollars are every year expended in attempting to remove the mud and sand deposited by this tidal action.

Part III

THE LAND

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

traction. The cold outside does not shrink; but as t[he] interior loses in size, this crust becomes wrinkled, in a ma[nn]er which may be compared with the wrinkling of the sk[in] of an apple which is drying.

Movements of the Crust. — There are many proofs th[at] the crust of the earth is in movement. Usually the[se] movements are so slow that they can be detected on[ly] after long intervals of time; but sometimes rapid chang[es] have actually been witnessed. The proofs of these mo[ve]movements may be said to be of two kinds, historical an[d] geological. While the historical proofs may perhaps appe[ar] to be most conclusive, they are in reality much less impo[r]tant than those of a geological nature.

In certain places the land has been known to move during earthquake shocks, and to remain either higher or lower than before the shock. [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Fig. [illegible]
Horizontal rocks on the plains of Kansas.

and [illegible] and [illegible] 29). They have be[illegible] bodily raised w[illegible] very little distur[illegible] ance. In mountain[illegible] and less prominent[illegible] elsewhere, the [illegible] have been [illegible] from their horizont[illegible] position, and [illegible] to assume incli[illegible] attitudes, which [illegible] often very complex. These changes commonly assume [illegible] of two forms, either (1) fold[illegible] ing or (2) faulting, which [illegible] [illegible] [illegible]

Fig. [illegible]
[illegible] fold.

the roof would repres
the dip, and the ri
pole, or any line para
to it, the strike.

In some cases
rocks break or *fault*
stead of folding (F
96), and some folds gr
ually change to fau
There is much compl
ity in faulting, parti
larly when the fau
extends across
that have already b
folded, and so more

[illegible]

[illegible]

[illegible]

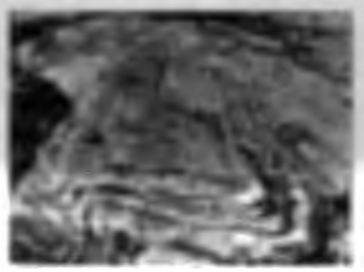
center of the volcano, becomes filled with solid lava whe[n] the volcanic action ceases; and sometimes it tries to reac[h] the surface along other planes, breaking the rock open an[d] filling the cracks with lava, forming *dikes* (Fig. 99). The[y] are very abundant in regions of volcanic action, and the[y] often occur in places where such action was once presen[t], being the roots of old volcanoes. Such dikes are extremel[y] abundant in New England, where they may be see[n] in great numbers cutting across the rocks of th[e] seashore.

In some of the deep part[s] of the earth, in the center of mountains, these intrusive [illegible]

[illegible]

coarser, because they could not cool so rapidly. Therefo
igneous rocks vary in two ways, in coarseness and in che
ical composition, and hence in mineral constitution. All
these varieties are given names, but their study belongs
geology.

Metamorphic Rocks. — Though they were not mad
metamorphic rocks resemble the igneous in the fact t
they are formed through t
partial agency of heat, and
the fact that they are crys
line. They are the least i
portant group, but in so
places, such as New Engl
and Canada, they are the m
common of rocks. They



particularly near the coast, because here the ocean water
so quiet that the particles must settle. In quiet bays,
fine-grained rocks may be deposited close to the shore;
on more exposed coasts, the sediments of the shore line

coarse-grained, and as the distance
the coast increases, they become
in texture. Since the ocean bottom
usually nearly level, these fragments
spread out in layers which are
horizontal, though where the bottom
inclined, the layers are inclined with
Sometimes the supply of sediment
either in amount or in kind, and so
layer may be deposited on another;
this gives the stratification that

Bricks are consolidated by heat, and in the earth heat o[illegible] acts in a similar manner. All rocks in the earth are fi[illegible] with water which is slowly percolating through them. T[illegible] water is dissolving substances from one place and deposi[illegible] them in others, and in this way many rocks are being c[illegible] solidated. Carbonate of lime and some compound of ir[illegible] are the common rock cements; and these, perhaps aided [illegible] one of the other causes, bind the rock particles together.

Geological Chronology. — By a study of the rocks, the m[illegible] facts of geological history have been determined in a m[illegible] or less satisfactory manner. We know something of [illegible] history of the globe, and the rocks form the pages and [illegible] ters of this history. The rock record is often very [illegible]

divide the history into stages, each stage representing an
advance in the development of life on the globe. For th[is]
purpose, names are used to signify the stages, as is indicat[ed]
in the table below, which is a simple one from which t[he]

TABLE OF GEOLOGICAL AGES.

CENOZOIC TIME. Age of mammals.	Quaternary	Man assumes importance, particularly in the upper part. In the first half the Glacial Period prevailed.
	Tertiary	Mammals develop to remarkable variety and to great size, while reptiles diminish [illegible]
[illegible]	[illegible]	Birds begin to become important, [illegible] [illegible] and higher [illegible] [illegible]

[illegible]

[illegible]

[illegible]

even hundreds of thousands, but millions and probably hu[ndreds] of millions of years. The evidence is overwhelmin[g], and no geologist finds reason to doubt it.

The gorge of Niagara, 200 or 300 feet deep, and 7 mi[les] long, has taken not far from 10,000 years for its formatio[n]; how much longer was the time occupied in forming the ca[ñon] of the Colorado, whose length is 200 miles, and whose dep[th] in places is over a mile! Yet these were formed in la[te] stages in the development of the continent.

We watch a volcano for a century, and, at the end of th[at] time, find its general form to be the same as at the begi[n]ning; yet most of the volcanic cones of the world w[ere] begun not earlier than the commencement of the Tertiar[y]. Studying the rate of deposit of the sedimentary rocks of t[he] ocean, we find that even where the deposit is rapidly ma[de] but a few feet are laid down in a single century [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

CHAPTER XIII.

DENUDATION OF THE LAND.

Underground Water. — When rocks are deposited in [illegible] oceans, the crevices between the particles of sediment [illegible] filled with water. In even the densest of rocks there [illegible] cavities, and through all of these, water is slowly percolat[illegible] as underground water. Added to the supply originally [illegible] the rocks there is a constant body of water entering at [illegible] surface. When rain falls upon the land, a part is returne[illegible] to the air by evaporation, a second portion flows away [illegible] surface water, and a third part sinks into the ground. [illegible] then begins an underground journey through [illegible] course of which much work is done. [illegible]

escape of certain gases which gave to it much of its power; and it is often the result of chemical changes in the presence of the air. Even in the earth, for one reason or another, the water at times deposits some of its dissolved load. This is one of the ways in which rocks are cemented; and it appears to be one of the causes for the formation of some of the valuable mineral deposits.

Underground water is also engaged in the work of changing some of the minerals of the rocks. It actually causes a decay of some minerals, and brings about very important changes in others. This is one of the ways in which the rocks are broken into fragments, and soils formed. The

roof. They are formed because on entering the cave the wate
loses some of the carbonic acid gas which gave to it its so

vent powers, and thereby has it
ability to hold in solution de
creased. By the gradual lower
ing of the land, the roofs o
these caverns are sometimes de
stroyed, and the streams tha
occupy them are changed to sur
face rivers. Where a part of th
roof remains, a natural bridge i
sometimes formed (Figs. 1[illegible] an
1[illegible]).

Springs and Artesian Wells.

pressure; and this is sufficient to force it upward towa[rd]
the surface, to a height nearly as great as that of the pla[ce]
where the water enters the ground.

If this water-bearing layer is pierced by a well-boring,
the water will rise in the well as high as the pressure
can force it; and if the place at which the well is bore[d]

Fig. 133.

Conditions favoring artesian wells (c, d, e), where the rocks are inclined [illegible]

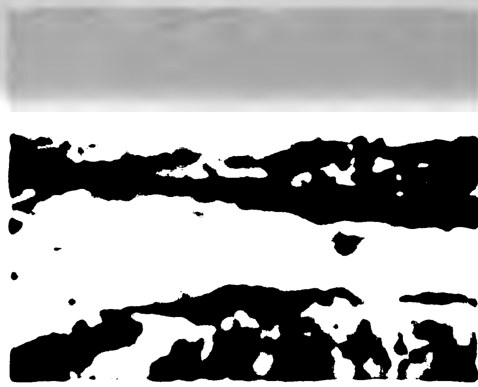
[illegible]

quartz grains in sandstones that have been produced by t[he] decay of rocks in which quartz was one constituent. T[he] clay of such rocks as shale is mostly the product of t[his] rock decay. Another result of these changes is to furni[sh] *dissolved* mineral substances to river water, and hence [to] the sea.

Of the *mechanical agents*, perhaps the most importan[t is] that of *change in temperature*, which, however, affects o[nly] the very surface rocks. In the regions which experien[ce] great temperature ranges, the rocks become warmed du[ring] the day and cooled at night. This introduces an altern[ation of] expansion and contraction, which causes fragments to [be] split from the rock surface. If the temperature desce[nds] below the ...

it is also in regions where a deep soil covering protects the rocks. Upon exposed ledges, weathering is rapid; and this is particularly true of cliffs, where the fragments drop to the base in the form of a talus (Figs. 118, 122), leaving the rock-face bare to future attacks. Then also, weathering is more rapid in some kinds of rocks than in others.

to man is the formation of soil. In many parts of the
the soil is the result of rock disintegration (Fig. 139),
in some places, particularly in the tropics, this residual
(so called because it is largely composed of the insolu
residue of rock decay) has a depth of 100 or 200
In this country it is of particular importance in the South
States, the soil of the Northern States being largely the re
of glacial action, and being a transported soil. Anot



important effect
this rock decay
that it furnishes
shows the la

the mountain bases. This form of erosion merges into that of rivers. In some places (Plates 20, 21, and 29) rain-erosion has carved the soft clay of the arid lands into a series of fantastic and remarkable forms.

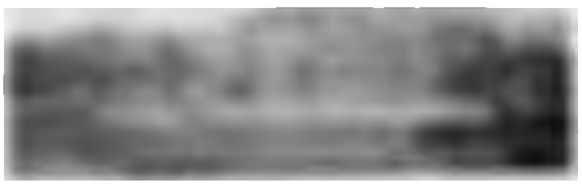
Gravity is an important factor in this and other kinds of erosion; but even when unaided by any of the agents of

carry substances in solution, but some have a little, w
others carry great quantities; and in desert regions,
rivers are sometimes so full of dissolved substances, t
the water tastes bitter or salt.

Armed with its load of sediment, the river cuts the s
of its channel, and deepens its valley; and by swinging f
one side to
other, it broad
the valley slig
ly. Thus by
erosion, there
produced a
tively deep
narrow chann
gorge, or a ca
In arid regi
where weather
is of little imp
tance, this is
prevailing typ
river valley.

sediment. With the hardness of the rocks there is als
variation; for a river cannot cut its channel so rapidly
a hard granite as it can in a soft clay.

From this it will be seen, that the rate and kind of wo
that a stream is doing, varies greatly according to circum
stances; and it follows that river valleys must present ve
different characteristics. Some are narrow, others broad
some deep, others shallow; some have rapid slope, othe
have a gentle flow, etc. In carving the land, river stream



upon the hills and valleys as unchanging and unchangeab[le] but rather as things of life, with a past history to be re[ad] and a future to be predicted.

REFERENCE BOOKS.

Aside from those to which reference has been made at the close of [the] preceding chapters :—

Lyell. — Principles of Geology, Vols. I. and II. Appleton & Co., New Y[ork]. Eleventh edition, 1872. 8vo. $8.00. (This is the great geological trea[tise], especially complete on the subject of denudation.)

Shaler. — First Book of Geology. Heath & Co., Boston,

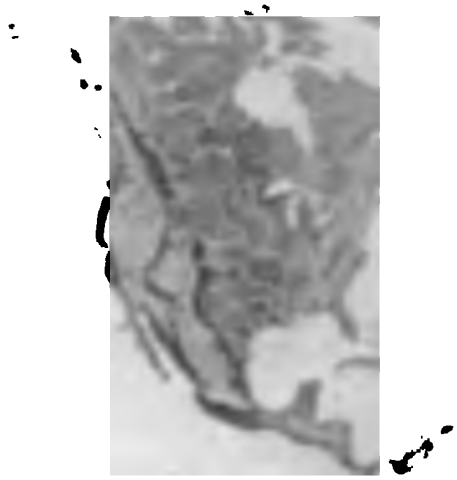
[illegible]

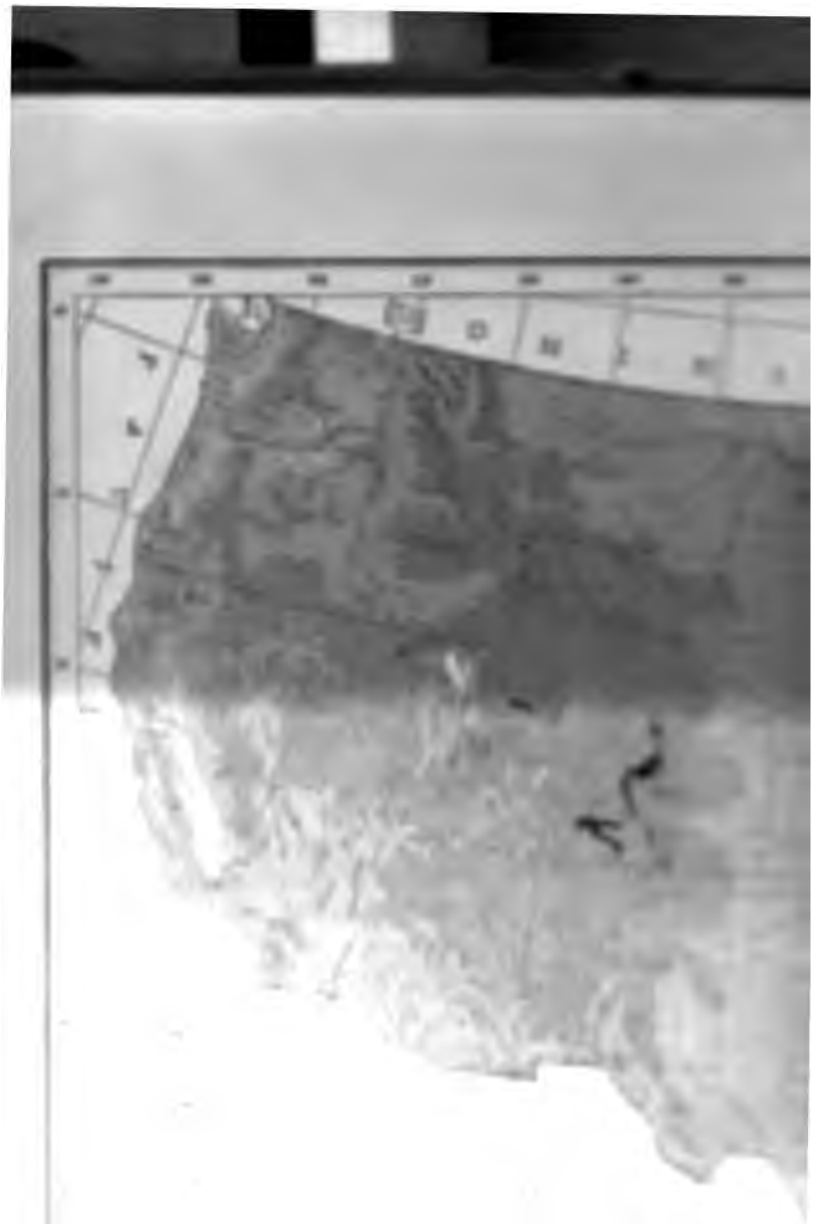
[illegible]

[illegible] — [illegible]

same difference in size between the eastern and the weste
group of continents. The American continents have a
average breadth of but little more than 2000 miles, wi
the average breadth of Europe and Asia combined, is ov
6000 miles.

As has been described in Chapter IX., the oceans for t
most part consist of great submarine plains or plateaus, he
and there broken by gently rising ridges, or occasionally b
steeply rising volcanoes or sharp mountain ridges. The gr





[redacted]

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

[illegible]

[illegible]

CHAPTER XV.

RIVER VALLEYS

General Description. — A river is a natural drainage li on the land, and it us ally occupies a val which has certain qu definite characteristi

these differences in streams, the two most important being the position and kind of rock in which they occur, and the stage in development which they have reached.

Only a very few years ago, river valleys were believed to have been formed by some earth convulsion, or some unusual force, and it was thought that rivers occupied these

down a slope, in its erosion the river reaches lower lev
near its mouth than higher up in its course. Until
line of easy slope is reached, erosion exceeds weathering
(Fig. 134); but then, since erosion is checked while weath-
ering continues, the latter produces its most marked effe
and the valley gradually broadens, while the hills slowly we

the gorge or cañon (Figs. 136, 137); and among moun[illegible] tains, where the elevation and slope are great, erosion [illegible] exceeds weathering that the gorge is the characteristic [illegible] valley (Fig. 134).

During the time when erosion exceeds weathering,—that is during youth,—the resulting valley is deep and relatively narrow; and wherever we see this kind of valley, we may [illegible]

increases. With the broadening valley, and the decrease river slope, the conditions favoring floodplains are broug about; and since the first and most rapid development is the lower part of the river, in this stage the valley may co sist of three quite different parts,—a lower flood-plain course, a middle portion, and an upper torrential part, wi

gorges and waterfalls. T majority of streams ha reached this stage, a this is why, in describi a river, it is commonly sa that it consists of thr [illegible]

While the prevailing type of mountain stream valley i that of the gorge (Fig. 134), there are mountain valleys o great breadth and depth. These are not true stream valley but great synclinal valleys of rock folding (Fig. 140) whic the rivers have occupied because of their convenient locatio After passing through a deep defile (Fig. 144), a tiny stream may emerge into one of these great, park-like valleys (Fig 143 and 225); an there we see, sid by side, the valle of stream forma tion and that o rock folding.

A still more important cause for the change of dividin
found among tilted rocks. If the layers of a series of st
stand in the monoclinal attitude, and if these alternate

hardness, the soft lay
weather more rapi
than those which
hard, and which, beca
of this fact, tend to
main above the gen
level (Fig. 201).
such a case, the bigg
points do not shift

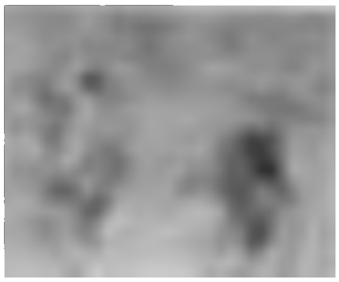
of its development, the different parts of a river may exper
ence entirely different accidents, and the resulting vall
will be *complex* or *composite*. Any single part of a stre
may also suffer a variety of accidents.

Land Movements. — Land movements are among the m
common accidents which interfere with normal developmen
and these are of three kinds: (1) broad uplifts, (2) dow
ward movements, (3) folding which accompanies mount
formation. With the general uplift of a country, strea
are given new life, or *rejuvenated*, and we may then fi
a narrow gorge cut in the center of a broad valley. Whe
long period of denudation the uplift gives new powe

[redacted]

[redacted]

The change in climate which produces glaciation, t
covers all the country with ice and buries the valleys. T
the margin of the snow-covered area, streams may be s
rated, and an entire change in the drainage be caus



[redacted]

because in the conflict between denudation and the intern[illegible] forces of elevation, the latter are more powerful and [illegible] the streams either constantly or intermittently at work [illegible] valley formation.

REFERENCE BOOKS.

From the text books of geology, previously referred to, one may [illegible] additional information upon some parts of the subject treated in this chap[illegible]

Important articles on the Development of Rivers will be found in [illegible] National Geographic Magazine, Washington, D.C., Volumes I. and II. [illegible] are from the pen of Professor W. M. Davis. This magazine is a very [illegible] [illegible]

[illegible]

present to distribute the sediment over the ocean betw[illegible]
Nearly tideless seas, such as the Gulf of Mexico (Fig. [illegible]
or the Mediterranean, are particularly liable to have [illegible]
opposite the stream mouths.

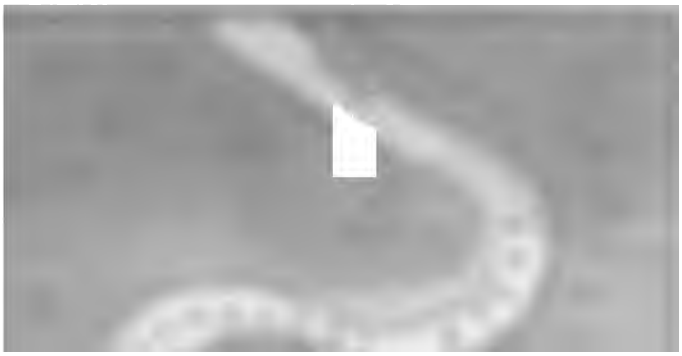
roughly triangular, or like the Greek letter Delta [illegible] whence its name. This is really a partial though accordi[…] distorted cone, not unlike the fan delta itself (Fig. [illegible]).

Floodplains. — Rivers are very often given more load th[…] they are able to carr[…] and of necessity the[…] are obliged to depo[…] some. The materia[…] sometimes deposited[…] the form of bars in t[…] stream channel, or[…]

Fig. [illegible].
Diagram to show the mode of formation of a delta.

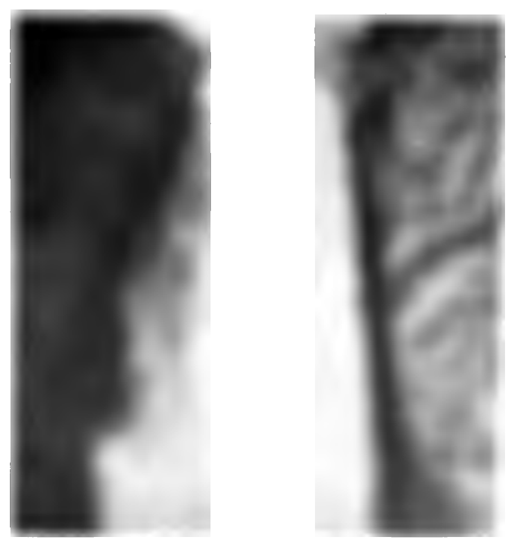
other times it is spread over the valley at one side of t[…]

Sometimes the broad floodplain is in part a delta, whi
has been left inland by the encroachment of the delta up
the sea. In the Mississippi valley, the delta begins to
above the northern limits of the state of Mississippi, an
has grown outward into the Gulf, filling the estuary whi
existed there, and transforming it to a broad floodplain
we now find it. This change is something like that whi
would happen if the streams now entering Chesapeake Ba



in position. The river is eating its way into the floodp
on the concave bank, and depositing upon the convex b

(Figs. 138-1[illegible], in wh
the dotted areas re
sent sand deposits). T
process of change c
causes the river to
across the narrow neck
land between two p
of the curve, and t
shorten the course
abandon the old cou
In delta and floodp
regions, there are num
[illegible]



miles in a course nearly parallel to the stream which th
would join; and in some rivers, the tributary streams h
been so far deflected that they enter the sea independentl

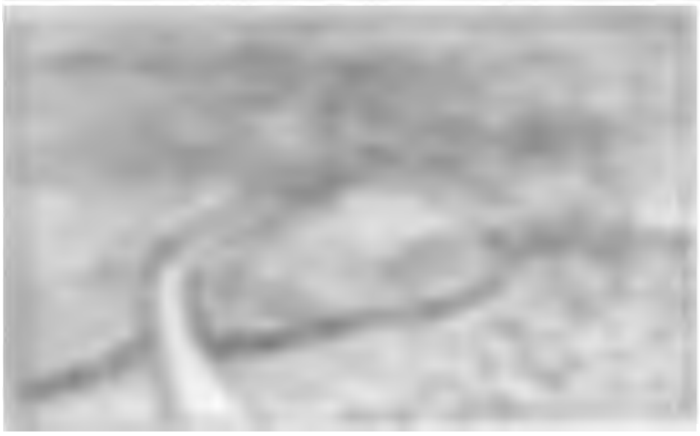
Waterfalls. — When for any reason a stream has a sudd
descent in its channel, waterfalls or rapids are produ
(Figs. 161-166); and we cannot separate the two phenom
ena, because there is every gradation between them. Th
are many ways in which an unnaturally steep slope may
introduced into the stream channel. One of the most co
mon means is by the accidental diversion of the stre

from its course. The gr
majority of waterfalls in
United States have
caused by changes in
stream courses, the re
of some interferences
part of glacial deposits.
result of these glacial
circumstances. In
valleys in many
rivers have been turned

are, the time occupied in cutting the gorge from Queenstown to the base of the falls, is somewhere between 7000 and 10,000 years. The falls of St. Anthony, in the Mississippi valley, are of the same origin, and have had nearly the same history; and the same is true of a vast number of waterfalls in the northern states of the Union.

Any other obstacle in the way of a stream will transform it into a waterfall, such for instance as the folding of some

been newly added to the continent, when filled with wa[illegible] are formed into lakes. This is the origin of the large nu[illegible] ber of lakes in Florida, and of Lake Drummond in the Di[illegible] mal Swamp. Others may be produced during and as [illegible] result of the natural development of streams. Such lake[illegible] as the oxbow cut-offs described above (Figs. 135 and 13[illegible] or those formed by the irregular growth of deltas (Fig. 13[illegible] are dependent upon the development of streams.



cut down, and thus the lake be speedily drained. Or if after emerging from the lake, the stream finds itself precipi-tated over some steep slope, its power of working is so con-centrated by this waterfall, that it rapidly wears a channel, as has been done by Niagara between Queenstown and the falls. Niagara is wearing back its falls towards Lake Erie, and given time, as a result of this concentration of work, it will so lower the outlet as to completely drain Lake Erie.

Lakes may be partially or entirely destroyed by evapora-tion, as has been the case in the great interior basin of the

than the down-cutting of the outlet. In the glacial belt
northern United States, where lakes of all sizes were form
when the ice retreated, we find abundant illustration of ev
stage in the destruction of lakes. The more shallow of th
have been transformed to swamps, which are usually a fi

stage in the process
lake destruction (F
172). After the se
ment has elevated the b
tom of the lake nearly
the surface of the wa
vegetation commence

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

CHAPTER XVII.

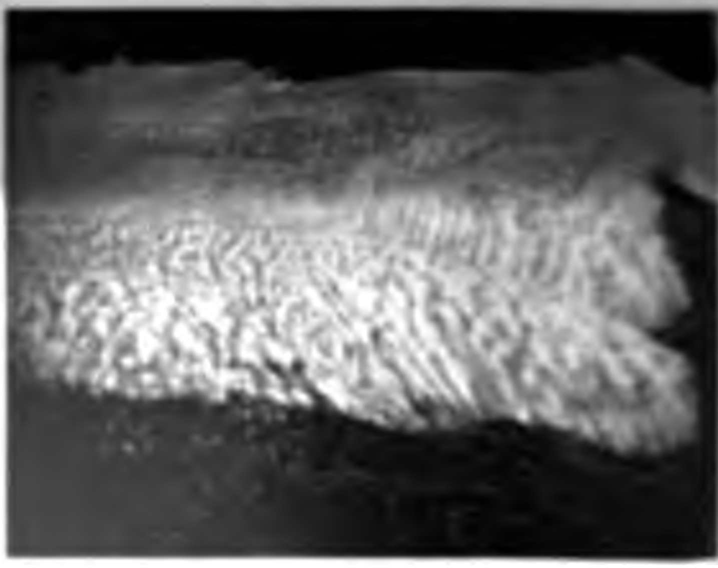
GLACIERS

Cause of Glaciers. — A glacier is an accumulation of sn
for the most part solidified into ice, which is engaged
a slow movement from one place to another. Where
snowfall is so great that the warmth of summer is
to entirely ...

mountain valleys, and is particularly well developed am
the Alps (Fig. 171). We also find valley glaciers am
most of the mountains of Alaska (Plate 20), in Bri
Columbia, in some of the high mountains of Washingt
such as Mt. Shasta (Fig. 174), and in several places
the Sierra Nevadas (Fig. 177). The glaciers of the s
are small and insignificant, but those of Alaska are am

the best develop
in the world. V
by glaciers are
so many more
seen in other

of rock material. Some of this is supplied from the valley sides, which are subjected to the action of weathering, and from which avalanches are not uncommon. As a result of this, the margin of the valley glacier is usually lined with rock fragments, to which accumulation the name lateral moraine is given. Where two valley glaciers unite, the



from beneath. This material also is carried by the ice down the valley in the form of a *ground moraine* (Fig. 179). After a while, the glacier comes to an end at the place where the melting is equal to the supply of ice. Here much of the material that was brought on the back of the ice, or beneath it, is deposited at the front margin, forming a *terminal moraine* (Figs. 177 and 179).

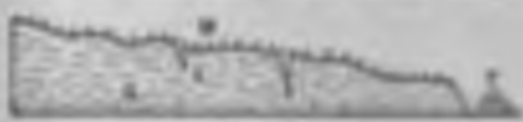


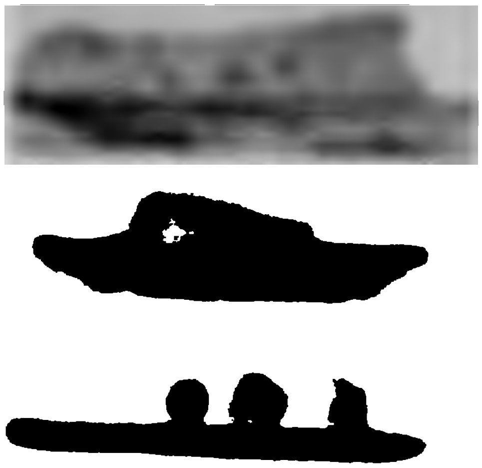
Fig. 179.
Section of a glacier. M, medial; T, terminal; and G, ground moraines.

there is some reason for thinking that it is nearly two mi[illegible] in depth, even at the margin, while in the interior [illegible] depth may be over five miles. But about the [illegible] conditions existing on this sheet of ice we have very [illegible] knowledge, for this part of the world is almost [illegible] unexplored.

Within a few years, our information concerning the Green[illegible] land ice sheet has become very much increased. Sev[illegible] parties have examined it along the coast, and others [illegible] passed into the interior of the Greenland continent. [illegible]

the margin, [illegible]

[illegible]



ing into the ocean (Fig. 182). As the ice moves into the sea, the buoyancy of the water causes it to break into fragments, which then drop into the ocean and drift away. Carried by the currents, these bergs may pass hundreds of miles from their source; and the Atlantic steamers not uncommonly encounter large icebergs that have been derived from the Greenland glaciers, while upon the shores of Newfoundland these are often stranded. An iceberg is mostly beneath the water; for, in a regularly formed ice block, there are [illegible] parts below the surface of the water for every one part that is above. Therefore if an ice-berg of regular form projects [illegible] feet above the sea, there are [illegible] feet below the surface of

(Fig. 184). But the most remarkable effect, was the p
duction of ice sheets of thoroughly continental charac
both in northwestern Europe and in northeastern Americ

The entire north temperate zone does not seem to ha
been occupied by a glacier, but there appear to have be
several large sheets, one set in Europe and another i
America. It is not certain whether these were connect
with the Greenland glaciers, but there seems reason to dou
whether there was such a connection. The extension of t

[redacted]

at present. Since no land projects above it, the Greenl glacier is not able to carry morainal material upon its s face; and the same appears to have been true of the con nental glaciers of the United States and Europe. Like t Greenland glacier, each of these ice sheets moved from a central region, in case of eastern America apparently in the region of Hudson Bay or Labrador; and as they mov they dragged rock material from northern towards south regions. When the ice disappeared, much of this mater was left, just as would be the case if the Greenland glac should melt away. As in the Greenland and valley glacie the front margin of the

[redacted]

[redacted]

[redacted]

Fig. [illegible]

[illegible] pebble covered with glacial scratches.

[illegible] from the [illegible] highlands. The [illegible]

and these young valleys are narrow, steep-sided, cañon-like gorges, in which waterfalls are common. We find illustrations of these post-glacial valleys in almost every part of the region occupied by the ice. Side by side we may often see the pre-glacial valley, with its broad, gently sloping sides, and the narrow, gorge-like channel of post-glacial origin. These may often be found in the same valley, the stream for part of its distance occupying its pre-glacial course, and in places flowing in these post-glacial trenches.

So pronounced has been the effe

[redacted]

CHAPTER XVIII

THE COAST LINE

General Statement. — The seacoast is a place of very active change, for here a very slight movement in the land registers itself distinctly in the outline of the shore. Materials are being brought by various agents and deposited in

[redacted]

made forms which have been partly submerged bene the sea. Figure 231, representing a part of this co is a particularly good illustration of these irregulariti

The coast of northern Eu rope illustrates the sa type; and on the Ameri coast, not merely i Maine furnish an illus tion, but from this to Florida, there are ab dant instances of same effect of land su

Florida, is being built outward by the accumulation
sediment that the waves have not been able to distribu
over the sea bottom. This sediment is brought to the s
by the rivers, and is piled by the waves into sand banks a
bars; and these bars extend as long islands parallel to t
coast (Fig. 194), being separated from the mainland
shallow bodies of water in which salt marshes are oft
present.

Effect of Waves and Currents. — On exposed coasts,

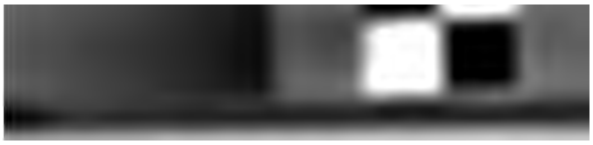
size and position. In some places, where the direction of the currents is favorable, permanent bars, or spits, are built out from the land (Fig. 196). Sometimes they are curved, and such sand bars are known as *hooks* (Fig. 197).

According to the conditions under which they are working, there is a very marked difference in the action of these oceanic agents. On exposed headlands which jut into the sea, the action of waves is violent, and the coast line is [illegible]

cannot be maintained; and where a hard rock is crossed by a less durable one, the coast is rendered irregular (Fig. [illegible]).

While these peculiarities of coast line may be found developed in many parts of the earth, the tendency of the waves and currents is to render the coast line always more regular. Materials are worn by the waves from the headlands and drifted into the bays which they tend to fill. In the course of time [illegible]

at the southern end of Florida (Fig. [illegible]). In the [illegible]
ocean, particularly in the South Pacific, the coral grow[illegible]
forms ring-like islands, which are known as atolls (Fig. [illegible]
Sometimes these are nearly perfect rings, enclosing an ar[illegible]
of water which is connected with the sea by a small openi[illegible]
The atoll rises above the level of the sea to a height suf[illegible]
cient for the growth of trees, and many of these islands a[illegible]
inhabited by man. The reason for their elevation above t[illegible]
sea is the washing action of the waves, combined with t[illegible]



cutting of waves (Fig. 232), of the building of bars an[d] hooks (Fig. 197), of the formation of beaches (Fig. 20[illegible]) and indeed of nearly all the phenomena of the seashore. Since many lakes are nothing but river valleys that hav[e] been dammed through some agency, both islands and cape[s] are often produced. These occur where the unevenn[ess] irregularities existed on the side of the valley which ha[s] been filled wi[th] water. Whe[re] there were trib[u]taries in the stream which ha[d]

[redacted]

CHAPTER XIX.

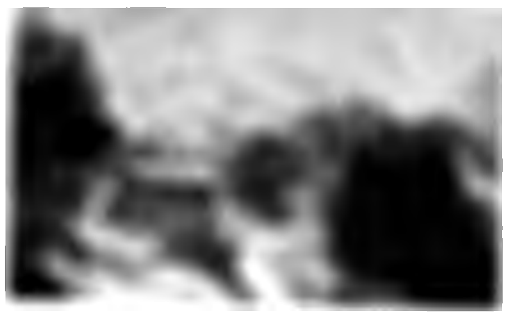
PLATEAUS AND MOUNTAINS.

Plateaus.—A plateau is a level-topped area at a consi
able elevation above the sea. In many respects it resembl
a plain (Figs. 250 a
251), but usually is
so level, and the

Since plateaus are elevated above the general level of
country, they are often very deeply carved by river
Some of the most remarkable cases of deep, narrow
valleys are found among high plateaus. Nowhere is
better illustrated than in the high plateaus of Utah
Arizona, through which is cut the remarkable cañon of
Colorado (Fig. 142 and Plate 29). In this respect
there is a difference between plateaus and low plains;

from the southern end of South America to the northern
part of Alaska.

A set of rock folds forming a great mountain series
generally known as a system. The Rockies form a system
of mountains, and several systems combined form a cordillera
(Fig. 129). This is illustrated in the western part of the
country, which is crossed not only by the Rocky Mountains



Between mountain ridges and chains, there are ofte longitudinal valleys of considerable size, extending par- allel to the chains between which they occur. These ar among the striking features of mountains, and they ar generally occupied by streams which are evidently too smal to have carved such immense valleys. When the rock structure is studied, it is evident that these valleys repre sent either down-folded portions of the crust, or else perman

[redacted]

other danger than that coming from occasional volcanic eru-
tions and earthquake shocks. The crust of the earth i
not convulsed, but is folded with slowness. This is tr
even when the rocks break instead of bending. Fault
representing the breaking of the rocks along certain plane
are even now in process of formation in various parts of th
world.

If we examine a section of a mountain, we find the ro
strata extending from the earth on either side of the ridg
(Fig. 226); but their extension into the air has been pr
vented by d
evolution. Th

[redacted]

growth; for if mountains are folded no more rapidly th
streams are able to cut their channels, then their grow
must be remarkably moderate. Since there are other po
ble explanations for these transverse valleys, we must c
sider this explanation as merely an hypothesis.

Lakes are c
common amo
mountains, their o
gin in these pla
usually being
folding of the ro
which form th

peaks lose in elevation, the ridges are worn down, the streams have chosen the softer layers for their valleys, and the aspect of the mountains has become quite changed. This is the stage which has been reached by the Appalachians. These mountains were once much higher than now; and since they have long been exposed to the destructive action of weathering and erosion, they have lost their ruggedness, and are only

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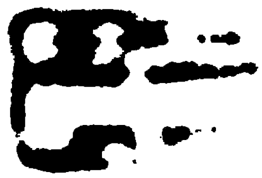
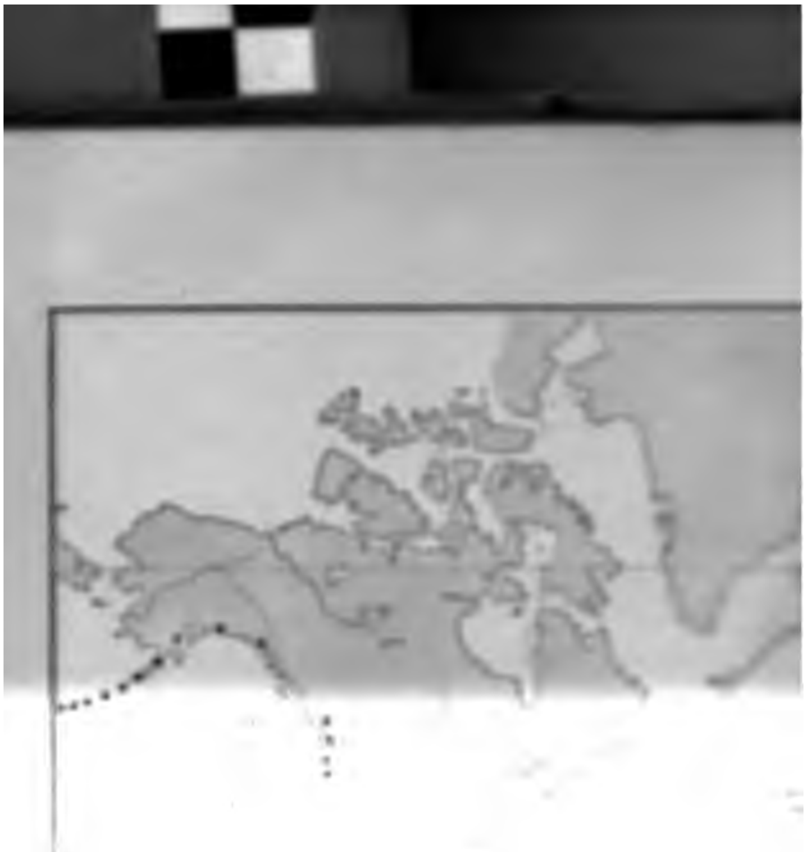




[redacted]

[redacted]

was imprisoned within it while the molten rock exist beneath the surface of the earth. Besides these, there a less notable quantities of other substances, chiefly some gases, such as hydrogen, chlorine, sulphurous gas, etc.

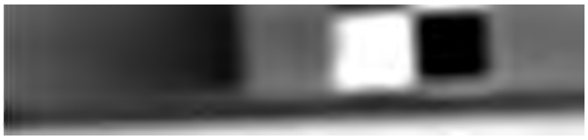
Some of the steam passes into the air as vapor, but much it falls to the earth near the volcano, producing very hea rains, and often causing deluges in the neighborhood of t cone. During an eruption there are often violent thund storms, in wh the rain is larg derived from t

that before they have been able to fall, they are blown by the wind currents to a considerable distance from the con[illegible] In the very violent eruption of Krakatoa, in the Straits of Sunda (in 1883), the finer particles of volcanic ash extend[illegible] so high into the air that they did not entirely reach the earth for a year or two. It is estimated that the fragment[illegible] reached a height of 50,000 feet; and this ash in the upp[illegible]

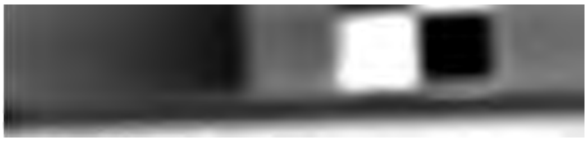
layers of the [illegible] drifted over the earth in the prevailing [illegible] winds, causing [illegible] [illegible]

1883 there were signs of activity in the volcano, and these in-
creased until August, when occurred the most remarkable
eruption of recent times. One half of the cone was entirely
blown away (Fig. [illegible]); and where the high volcanic island
existed, there is now deep water in place of a part of the
island. There are numerous other instances of violent erup-
tions, and in Iceland these are not at all uncommon.

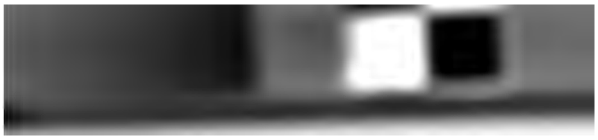
Many volcanoes have violent eruptions at one time and
then moderate action. This was the case with [illegible]



Violent eruptions tend to destroy the perfection of t
cone; and in the case of Krakatoa, the volcano was divid
into two parts, one of which disappeared into the air (Fig



the forces of denudation act upon the cone and wear it away. At first the regularity of the cone is destroyed by the gullying action of streams (Figs. [illegible] and [illegible]), then its size decreases, and finally merely a remnant of it exists. This remnant is always that of the central part of the cone, partly because this is the divide and hence less exposed to



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the time immediately preceding volcanic eruptions earth-quake shocks are very common, being apparently the result of unsuccessful efforts of the lava to force its way to the surface. As the rocks are broken apart, each step in its progress toward the surface produces a jar. When sufficient

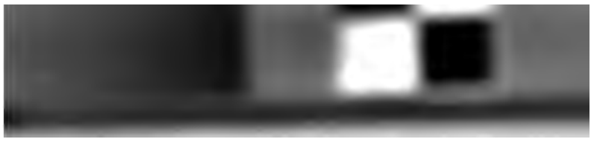
began eruptions like the other geysers of the Park. Whi
hot springs are very widely distributed, geysers are qui
uncommon. There are only three places in the world whe
they are features of importance, one being the Yellowston
Park, the second in Iceland, and the third in New Zealan
In all of these cases, the geysers are bringing to the surfac

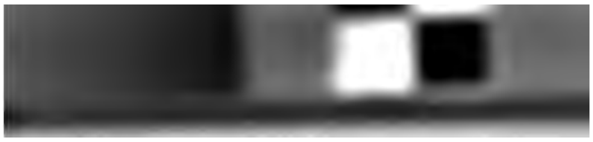
CHAPTER XXI.

THE TOPOGRAPHY OF THE LAND.

General Statement. — Land forms are of two kinds: (1) those that have been built by some agency and (2) those that have resulted from the combined action of building and carving. By far the greater number of land forms are of the last origin, and there are few that have resulted

Some parts of the earth are now being built up, others being worn down by one cause or another. As a result this, the surface of the earth presents most complex feature but if we look at the causes and influences that are at wo it becomes a much more simple task to account for the These may be briefly summed as follows: The crust of earth is in movement, in some places upward, in others dow ward, here by broad uplift or downsinking, there by the m local and intense upfolding or downfolding which accom nies mountain growth. Some regions are therefore u ually high, others low; some are mountains, others pla and still others plateaus. Denudation is ...





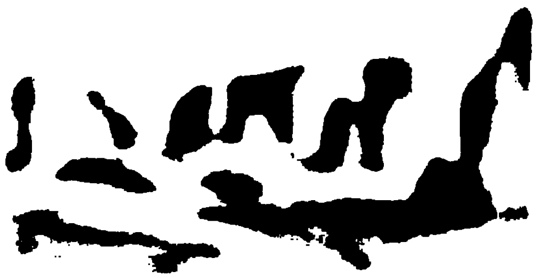
of this, the land surface presents many diversities. Uni
uniform conditions, denudation affects rocks differen
according to (1) their elevation, (2) their position, a
(3) their structural features. Moreover, the intensity
denudation varies; and as a result of these facts, land for
differ from place to place. It is impossible here to enter in
this subject in any considerable detail; but some of t
main principles may be briefly stated.

Much depends upon the ease with which materials may

Colorado (Figs. 221 and 221) with the Appalachians o
Adirondacks (Figs. 203 and 204).

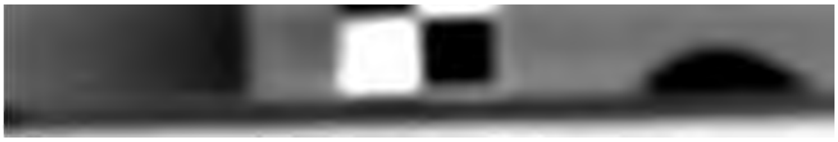
With conditions of aridity, the soil covering is
removed from the rocks, so that they are exposed to the
and hence, here also, angularity and ruggedness of topograp
prevail (Figs. 122 and 142 and Plates 29 and 29).
times the streams cannot carry the material furnished

there, and
of
highlands,
flow on the



rocks is taken advantage of by the waves, and the wea
places indicated by an indentation in the coast. Where t
rocks are jointed or broken, or where one layer is softer th
another, sea caves (Fig. 198), chasms (Figs. 199 and 20

and even small bays, may b
produced. The cliffs are n
so high nor so angular as i
the massive rocks (Figs. [illegible]
and 201); for, both by the wa
and by weathering, they a
caused to crumble and to a
sume a more gentle slope.



is typical of plateaus, and particularly of those in arid lands. On the seashore, the tendency to produce a step-like coast exists where the horizontal rocks outcrop in cliffs composed of layers of different hardness.

FIG. [illegible].
Effect of hard layers (unshaded) in the denudation of nearly horizontal strata.

With gently dipping rocks, very nearly the same kind of topography is produced; but the flat-topped areas are less distinct. In passing across a [illegible]

[redacted]

form of the coast differs entirely according to the direction of the dip. If the waves beat against a series of [illegible] ping toward the sea, they produce a gently-sloping [illegible], whose form and position are determined by a beach-line (Fig. 259). On the other hand, if the dip is away from the sea, the waves beat against a bluff (Fig. 260.)

When the strata are inclined at a high angle, the land

[redacted]

progress; that the land forms are still changing; that
have been different in the past; and that the future
find them different still. Some forms have reached
stage, and some another; but all are developing along
tain lines of a more or less definite nature, notwithstanding
the fact that the conditions are complex, and are
undergoing change themselves. Any intelligent stu
the earth's surface must be made with these facts clo
mind.

[redacted]

been so gullied that it is unfit for cultivation. A part of Mississippi has been transformed to a barren waste of clay, the features of which resemble those of the Bad Lands of South Dakota (Plate 21). The effect of the absence of forests is well illustrated in the arid lands, where the forest covering is absent because of natural climatic conditions. Here every rain gullies the land; and on the steeply sloping hillsides, the removal of the soil by rain and wind action has exposed the bare rock (Figs. 99 and 121).

[redacted]

[redacted]

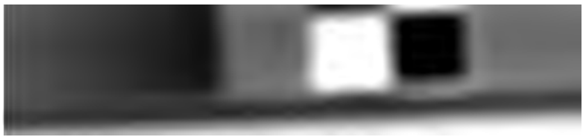
[redacted]

[redacted]

CHAPTER XXIII.

ECONOMIC PRODUCTS OF THE EARTH.

Soil. — The crust of the earth furnishes to man most
the material which he needs for life and comfort. T
rocks crumble to form soil, and upon this exist the pla
which furnish us directly or indirectly with



[redacted]

Since we cannot enter into a discussion of these, it will b
necessary to confine ourselves to a statement of what seem
to the author to be the most probable explanation. Witho
doubt, different coal beds have had a very different history
Some represent the drifted fragments of wood that ha
been deposited in an ancient bay or estuary, and the
buried beneath marine deposits. Thus if the Mississip
delta should be consolidated into rock and be elevated, the
would be coal seams formed where rafts of logs have be
stranded.

There also seems to be no doubt that some coal beds a
nothing more than swamps which were formed either

[redacted]

[redacted]

[redacted]

Colorado, which leads in the production of silver and lead, and is second in the production of gold; and Montana follows, leading in the production of copper, and second in the output of silver. The east excels in the production of non-metallic substances, and the west in metals.

This astonishing mineral wealth has, in no small degree, been responsible for our development as a nation; and there are still great undiscovered stores. There seems to be almost no limit to the possibilities in this direction, and our Alaskan territory promises to add to this wealth. Nature has been most prodigal in lavishing her favors upon this country, for she has given us nearly all that man could require. [illegible]

[redacted]

[redacted]

very much as water enters a turbine wheel and causes it to revolve. By means of a series of wheels, each revolution of the anemometer is recorded, and this may be transmitted by electricity to some place where an automatic record is kept in miles per hour.

Measurement of Evaporation. — The measurement of evaporation is made in inches of water evaporated from a surface exposed to the air. Almost any dish can be used, and the scale of inches be marked upon it; or the measurement may be made with a graduated scale. Since the rate of evaporation varies with the temperature, it is best to attempt to imitate natural conditions as nearly as possible, though this is not easily done. The best way is to place the evaporating pan in a quiet body of water, allowing it to float on the surface. There are various contrivances for obtaining a continuous record.

Measurement of Moisture in the Air. — The amount of the [illegible]

[redacted]

knowledge of the changes that have occurred in the preceding
and knowing what changes are liable to follow, predictions of greater
less accuracy are made, in some cases for several days in advance.
many respects these predictions are of great importance; but in addi-
to this result of the work, we are rapidly obtaining much scientific in-
mation concerning the air. We are also obtaining many facts rela-
to the general climatic features of the country, and of the world.
in these directions much less is being done than should be; for a
we know more about the air and its behavior, we may not expect
obtain more accurate predictions.

Upon a weather map (Fig. 80) the wind direction is plotted in the f
of a series of arrows pointing in the direction toward which the wind
blowing. The temperature is also placed upon them, and lines of eq
temperature, or isotherms, are drawn across the country. The press
of the air is also graphically shown on the maps by a series of

superior to this in many respects. A contour is a line of equal elevation. It is the line to which the sea would rise if the land were depressed to the depth represented by the height of the line. If we imagine ourselves near the seashore, the coast line is then the contour line of 0, and the 100-foot contour line is that to which the sea would reach if it were raised just 100 feet.

The contour map (Figs. [illegible], and Plate [illegible]) is made upon a horizontal scale which varies in different cases. In this country the usual scale is one inch to the mile: that is, every mile of country is allowed one inch. No allowance is made for the vertical element of the country. Thus if a region of considerable irregularity is being mapped, an inch on the sheet is made to represent one mile in a horizontal direction. As one stands upon the side of a hill, and looks across a valley to another hillside at the same elevation, and a mile distant

[redacted]

SUGGESTIONS TO TEACHERS.

In the preparation of this book, the endeavor has been to state the subject in a purely descriptive manner. Nevertheless, the best way to learn physical geography is not to read about it, but, so far as is possible, to work out the points for one's self. Not merely does the laboratory method teach the subject better, but it trains the mind of the student in a far more valuable way than is done merely by

[redacted]

[redacted]

tions on the wind, temperature, and pressure. Such a study will crea
a real live interest, and make the students observers of the things
every-day occurrence, as well as train their minds in the habit
drawing logical conclusions from a series of observed facts.

CHAPTER V. — The study of cyclones and anticyclones receives
aid from the daily weather maps. On these the student will see the
and size of the areas, their rate and direction of progression, the amoun
and distribution of rainfall, the direction of the winds, their spi
tendency, the left-hand whirling, etc. He will observe how the win
change from day to day, and what relation they bear to the areas
high and low pressure. He can predict the changes and study the
in connection with the weather of his own immediate neighborhoo
The storm paths and their irregularities can be studied with the aid
the Monthly Weather Reviews.[1] From the weather predictions

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powers of observation and arouse their interest; and the skillful teacher may make this the basis upon which to build a real understanding of the action of rivers. The key to success in this direction is to tell the student only so much as is absolutely necessary, but to make him tell the story, not from memory of what the book says, but upon the basis of a series of observations which necessarily lead to these conclusions.

It is not necessary to find illustrations of all phenomena in the field, though the more, the better; but the object is to teach the student how to see for himself, so that he may see other illustrations whenever he happens to come upon them. Where it is not feasible to study the phenomena in the field, photographs or lantern slides make a fair substitute.

CHAPTER XIV. — With a set of Physical Maps[1] of the continents, there is opportunity for study of the grander features of the land. These are much more naturally shown upon a relief globe.[2] The distribution

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The Earth. — What reasons have we for believing that the interior is highly heated? What is the probable condition of the interior? What are the movements of the earth? What are the peculiarities of its revolution? What is the cause of the seasons?

The Moon. — What are its movements? What is perigee? Apogee? Why is one side of the moon never seen from the earth? What are the probable conditions on the moon?

Comets, Shooting Stars, and Meteors. — What are comets? How do they move? What is the origin of meteors? Why do they glow?

The Stellar System. — What is the probable number and distance of the stars? How are they arranged? What and where are nebulae?

Symmetry of Solar System. — What points of symmetry are noticed? What are the distances between the members? Illustrate.

The Nebular Hypothesis. — State it.

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CHAPTER V.

STORMS. PAGES [illegible].

Cyclonic Storms. — What is a storm? What are some of the causes of storms? What are the two kinds of cyclonic storms?

Hurricanes: *Description.* — Where do the hurricanes begin? The typhoons? What changes are noticed as the storm comes and passes over a place? What is the eye of a storm? How is the air moving in the storm?

Effects. — What is their effect upon vessels? Upon the coast? State some instances.

Path. — What is the natural path in the North Atlantic? How do they sometimes diverge from this? What is their path in the Pacific? South of the equator? What is their size? Where are they most [illegible]

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Distribution of Snowfall. — Where does snow fall? Where are glaciers produced?

Seasonal Distribution of Rainfall. — What is the effect of the migration of the belt of calms? How do the monsoons affect the seasonal rainfall? What is the reason for the winter rains of Washington and Oregon? For the irregularities of rainfall in the east?

Irregularities of Rainfall. — What is the normal rainfall? How does it sometimes vary from this? What are the effects of heavy downpours?

CHAPTER VII.

WEATHER AND CLIMATE. Pages [illegible].

Weather. — What is weather? Climate?

Tropical and Arctic. — What are the weather conditions of the belt [illegible]

CHAPTER [illegible].

FORM AND GENERAL CHARACTERISTICS OF THE OCEANS.
PAGES [illegible].

Distribution of Land and Water. — What are the main features of distribution of land and water?

Composition of Ocean Water. — What are the principal ingredients of salt water? How much variation is there in salt ingredients? What are the reasons for this?

Color and Phosphorescence. — What is the natural color of the ocean? Why? Are there other colors? What is phosphorescence?

Exploration of the Ocean Bottom. — What reasons led to the belief that animals could not live here? How can the animals exist under the [illegible]

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warm surface water so shallow? Why are the surface temperatures [illegible]
constant?

Ocean Currents: *Planetary Circulation.* — What resemblance is [illegible]
between ocean and air circulation? What reasons are there for believ[illegible]
in a planetary, oceanic circulation?

The System of Ocean Currents. — What is the circulation in equator[illegible]
regions? What is the North Atlantic drift? What [illegible] of [illegible]
water entering the Caribbean? What is the origin of the Gulf Strea[illegible]
Its course? What is the Labrador current? Briefly describe the gen[illegible]
circulation of the North Atlantic. What are the conditions in the So[illegible]
Atlantic? What is the circulation of the North Pacific? What is [illegible]
Kuro Siwo? What is the circulation of the South Atlantic? What [illegible]
the main features of the oceanic circulation?

Cause of Ocean Currents. — What reasons are there for doubting [illegible]

[illegible]

most important? How are the mechanical sediments derived? H[illegible] are they accumulated? What are the kinds? How do they differ?

Deposition of Sedimentary Rocks.—In what position are they dep[illegible] laid in the ocean? What is the origin of stratification? What are [illegible] characteristic deposits in the sea? What are the characteristic s[illegible] mentary rocks on the land? What does this prove? How thick are [illegible] sediments. What does this prove? What is an unconformity?

Consolidation of Sedimentary Rocks.—How are rocks cemented? Il[illegible] trate. What are the common rock cements?

Geological Chronology.—What is the condition of the rock [illegible] What are fossils? How has a record of early life been obtained? W[illegible] does this show? Can the age be told by fossils? What is the differ[illegible] between age and stage? What do the names of the geological peri[illegible] really indicate? What does the name Carboniferous mean? [illegible]

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CHAPTER XVI.

Deltas, Floodplains, Waterfalls, and Lakes. Pages [illegible].

Deltas. — Where are delta deposits made? What is the alluvial fan? What conditions favor delta formation in the ocean? Why are lakes favorable places for them? How does the river flow over the delta? What are distributaries? How does the delta grow?

Floodplains. — Where are these found? What causes floodplains among mountains? What is the most common cause for floodplains? How may they merge into deltas? What effect would be produced by tilting the land? From changes of climate? What are the characteristics of floodplains? What is the course of the stream? What are oxbow cutoffs? How are the floodplains raised? How does the flood-plain material move down stream? What is the effect of the floodplains

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their former abundance? Have they occurred in all parts of the world?

Materials Erupted. — What substances are erupted? What is the cause of pumice? What are the effects of the steam? What is a mud flow? How does the lava flow move? What is the amount of the [illegible]? How does this differ from ash? What was the effect of Krakatoa?

Eruptions of Volcanoes. — How do these vary as to violence? Contrast the eruption of Krakatoa with those of the Lipari Islands. What is the case in Vesuvius? In the Hawaiian Islands? What kinds of volcanoes are the most violent? What are the three groups?

Form of Cone. — How does a volcano grow? What tends to destroy the cone? Where are they steepest? What is their angle of slope? How do lava and ash cones differ?

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adapted? When reached, why was its settlement relatively easy? What caused the development of the far west? What has determined the position of the towns of New England? What relation is there between the industries of the country and the surroundings?

CHAPTER XXIII.

ECONOMIC PRODUCTS OF THE EARTH. *Pages* [illegible].

Soil. — What is its origin? Its value?

Building Stones. — What is the origin of granite? What other stones are sold as granite? What are the metamorphic building stones? What is the origin of slate? Of marble? What are the causes of metamorphism? What are the sedimentary building stones? How abundant are they? What other mineral substances are used for building? [illegible]

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Islands, [illegible]
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[illegible]
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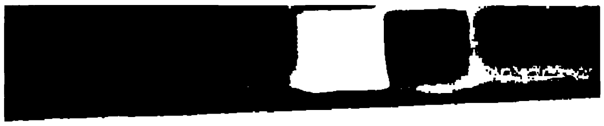

Samoan Islands, hurricane of, [illegible].
San Francisco, temperature of, [illegible].
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Sand dunes, [illegible].
Sands, [illegible].
Sandstone, [illegible].
Sargasso Sea, [illegible].
Satellites, [illegible].
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Saturn, [illegible].
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Sea caves, [illegible].
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Seasonal winds, [illegible].
Seasons, [illegible].
Seaweeds, importance to coast, [illegible].
Secondary waves, [illegible].
Snowflakes, [illegible].
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Soil, [illegible]; effect of forest on, [illegible]; motion of, [illegible]; glacial, [illegible].
Solar light, [illegible].
Solar system, [illegible]; symmetry of, [illegible].
Sounding, [illegible].
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[illegible] changes in, [illegible]; terminal moraines of, [illegible]; volcanoes in, [illegible].
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Weather predictions, [illegible].
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White glacier, Alaska, [illegible].
White Mountains, N.H., [illegible].
[illegible]

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"[illegible] chemistry."—[illegible]

Problems adapted to the above. By Professor Thorpe and M. [illegible] [illegible]

INORGANIC CHEMISTRY FOR BEGINNERS. By Sir Henry Roscoe, F.R.S., assisted by Joseph Lunt, B.Sc. [illegible]

OWENS COLLEGE JUNIOR COURSE OF PRACTICAL CHEMISTRY. By F. Jones. With Preface by Sir H. Roscoe, F.R.S. [illegible]

"[illegible]"—*[illegible]*

OWENS COLLEGE COURSE OF PRACTICAL ORGANIC CHEMISTRY. By Julius B. Cohen, Ph.D. With Preface by Sir H. E. Roscoe and Professor Schorlemmer. [illegible]

"[illegible]"—[illegible]

CHEMICAL THEORY FOR BEGINNERS. [illegible]

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